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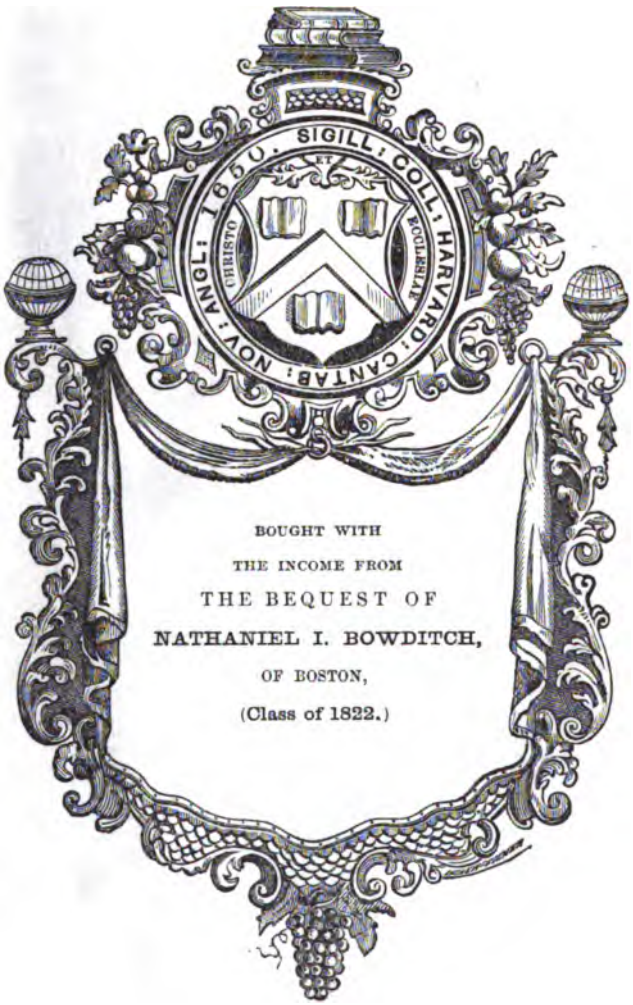

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Report

on the

United States Shipping Board
Emergency Fleet Corporation

on

ELECTRIC WELDING

and its

Applications in United States of America

to

Ship Construction

by

CAPTAIN JAMES CALDWELL, R.N.

Deputy Assistant Director of Materials and Private Agencies, London, England

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Emergency Fleet Corporation
Philadelphia, Pa.
U. S. A.
1919

COPY No.

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to

The Education and Training Section, Emergency Fleet Corporation

Report

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United States Shipping Board

Emergency Fleet Corporation

on

ELECTRIC WELDING

and its

Application in United States of America

to

Ship Construction

By

CAPTAIN JAMES CALDWELL, R. E.
Member Institution of Electrical Engineers
Deputy Assistant Director of Materials and Priority
Admiralty, London, England

EMERGENCY FLEET CORPORATION
PHILADELPHIA, PA.
U. S. A.
1918

Eng 5057.19.9

Philadelphia, Pa., April 20th, 1918.

Mr. Daniel H. Cox, Manager,
Division of Steel Ship Construction,
Emergency Fleet Corporation,
Washington, D. C.

My dear Mr. Cox:

At the termination of my period of service with the United States Shipping Board, Emergency Fleet Corporation, I submit my report herewith.

This communication is really a series of reports with an indexed preface. I decided to adopt this scheme of arrangement in view of your probably desiring to circulate certain of the contents, whereas for obvious reasons, other matters dealt with in the report would be of little interest outside the scope of your officials engaged in electric welding undertakings.

In this connection it is the expressed wish of Mr. E. B. Katte that Report No. 8, Sections "A" to "E", inclusive, be considered confidential and especially withheld from parties interested in the supply or manufacture of electric welding apparatus. Also, I should prefer circulation of Report No. 11 to be restricted to officials of the Shipping Board and naval officers.

I wish to take advantage of this opportunity to put on record my appreciation of the whole-hearted assistance and co-operation which has been granted me, not only by the officials of your Corporation, but also by shipbuilders and others with whom I have come in contact during the execution of my duties.

It would be invidious to refer individually to all who have given me the benefit of their knowledge and experience. At the same time I am particularly pleased to have had the freely offered assistance of Mr. Henry M. Hobart, who not only collected numerous valuable contributions contained in Report No. 17 but collaborated with me in the grouping together of other data. Indeed in the limited time at my disposal it would have been well nigh impossible to place before you this comprehensive report of up-to-date electric welding practices without Mr. Hobart's help.

For providing means to enable me to produce the report I have also to acknowledge the facilities provided by Mr. E. E. MacNary, head of the Industrial Training Department, who delegated one of his assistants, Mr. F. W. Tupper, to collect and classify particulars which I forwarded to Philadelphia from time to time.

Sincerely yours,
JAMES CALDWELL,
Captain.
Dep. Asst. Director of Materials and Priority,
Admiralty, London.

PREFACE TO REPORTS BY CAPTAIN JAMES CALDWELL, M.I.E.E., ADMIRALTY, ENGLAND.

Prior to returning to England, I submit this series of reports in which I have incorporated the results of welding investigations during my three months' stay in America.

During that time I have been loaned by the British Admiralty to the Emergency Fleet Corporation at the request of the United States Shipping Board.

The titles of these Reports are as follows:

Report Number One: Conclusions with Reference to the Use of Electric Welding for Ship Work. (Pages 11-21.)

Appendix A: Description of Electrically Welded Cross Channel Barge. (Pages 15-16.)

Appendix B: Detailed Discussion of the Application of Electric Welding to Ship Construction. (Pages 17-21.)

General Headings:

Electric Welding Systems

(1) Resistance Welding
  (a) Butt methods
  (b) Spot methods
  (c) Line methods

(2) Arc Welding
  (a) With bare metal electrodes
  (b) With flux covered electrodes
  (c) With carbon electrodes

Relative suitability of each system of welding to Ship Work.

Electricity Supply
  (1) Direct Current
  (2) Alternating Current

Relative Conditions
  Tensile strength
  Toughness
  Quality of metal
  Cost of power and equipment

Welding versus Riveting

Report Number Two: Brief Chronological Record of My Visits. This constitutes a key to the subsequent re-

ports, reference to each of which is introduced at its appropriate place. (Pages 23-33.)

Appendix A: Four District Meetings to Discuss Welding. (Pages 30-33.)

Report Number Three: Notes Relating to Each of the Shipyards Visited. (Pages 35-62.)

General Headings:

(1) Date of Visit
(2) Officials Interviewed
(3) General Remarks
(4) Method of Construction
(5) Workers
(6) Capacity
(7) Output
(8) Electric Welding
(9) Conclusions, etc.

Report Number Four: The Electric Welding Committee of the Emergency Fleet Corporation. (Pages 63-92.)

A—List of members
Minutes of first meeting
B—Minutes of second meeting
C—Minutes of third meeting
D—Recommendations by Naval Constructor Knox
E—Proposed Electric Welded Construction of 5,000 ton standard ship by Messrs. Ewertz and Knox.
F—Captain Caldwell's report to Welding Committee
(1) Propaganda in Britain
(2) Training of Welding Operators
(3) Preparation of work for Welding
G—Circular letter sent to shipyards
H—Circular letter sent to manufacturers of electric welding apparatus

Report Number Five: Description of the Ewertz type of Electric Welded Ship. (Pages 93-102.)

Report Number Six: Coleman Castweld Process of Seamless Steel Construction. (Pages 103-106.)

Report Number Seven: Applications of Electric Arc Welding to Ship Construction, developed by Mr. Bonner. (Pages 107-122.)

Report Number Eight: Mr. E. B. Katte's Investigations Relating to Arc Welding. (Pages 123-125.)
(a) Confidential Report

(b) Description and Record of Tests
(c) Specification of Welding Apparatus
(d) Specified Method of Making Tests
(e) Appendix
(f) Tests of Quasi Arc and other electrodes with alternating current.

Report Number Nine: New York Shipbuilding Company's Investigations Relating to Spot Welding. (Pages 127-135.)
(a) Description and remarks
(b) Photographs and tabulated test results.

Report Number Ten: The Holslag System of Arc Welding. (Pages 137-139.)

Report Number Eleven: British Admiralty Investigations in Electric Welding. (Pages 141-172.)
(a) Summary of opinions expressed by Admiralty Naval Constructors.
(b) Conclusions and recommendations.
(c) Analysis of results
(d) Application to new construction.

Report Number Twelve: Mr. James A. Osborne's Spot-welded Car. (Pages 173-181.)

Report Number Thirteen: Lists of Ship Parts for Which Various Authorities Require and Allow Electric Welding. (Pages 183-195.)

Report Number Fourteen: Mr. E. J. Rigby's Description of Welding with Flux-covered Electrodes and of the Quasi-Arc System. (Pages 197-203.)

Report Number Fifteen: Mr. H. G. Knox's Plan for Nomenclature for Various Kinds of Welds. (Pages 205-224.)

Report Number Sixteen: The Westinghouse Company's Activities in Electric Welding. (Pages 225-257.)
(a) Investigation of electric welding methods and control.
(b) Electric welding equipment.
(c) (1) Preparation of work for welding
(2) Arc and electrode data
(3) Added metal necessary
(d) Strength and structure of electric arc welds.
(e) (1) Micro photographs of welds.
(2) Sundry tables and charts.

Report Number Seventeen: The General Electric Company's Activities in Electric Welding. (Pages 259-361.)

General Headings.

A—Report by Mr. R. E. Wagner, Assistant Manufacturing Superintendent of the Pittsfield Works. This report comprises a good deal of information which has been accumulated at Pittsfield on electric arc welding. (Pages 261-296.)

B—Report of Mr. E. F. Collins and Mr. P. A. Meyer, both of the Industrial Heating Department of Schenectady Works. (This report comprises descriptions of a number of investigations and machines developed by the Industrial Heating Department. (Pages 297-309.)

C—Report by Messrs J. A. Capp and G. H. Wright of the Testing Laboratory of the Schenectady Works. This report comprises some interesting micrographic studies carried out by Mr. Wright on butt-welds. (Pages 310-319.)

D—Report on the subject of spot-welding by Mr. W. L. Merrill of the Power and Mining Department. Mr. Merrill has had charge of a great deal of very important work which has recently been done in the development of spot-welding machinery for heavy plates and for carrying out tests on welds made with such machines. (Pages 320-329.)

E—Report of Mr. F. W. Caldwell on a method of welding together copper and iron by means of the carbon arc. (Pages 330-331.)

F—Report describing an elaborate series of tests made in 1915 to compare the state of the arc welding art at that time. In these tests there were used carbon arc electrodes, bare-metal electrodes, flux-covered electrodes made by the General Electric Company, flux-covered electrodes made by the Quasi Arc Company of America, and also the oxy-acetylene process. Cost and quality comparisons of welds made by all of these methods are set forth in this report. (Pages 332-359.)

G—Report by Mr. W. J. Delles on apparatus used at the Schenectady Works for instructing workmen in the art of welding. (Pages 360-361.)

Report Number Eighteen: Protective Devices for Electric Welding Operators. (Pages 363-365.)

Report Number Nineteen: Comparative Data—Cost and Current Requirements with Bare and Flux-covered Metal Electrodes. (Page 367.)

Report Number Twenty: New York Navy Yard Investigations of Electric Welding. (Pages 369-392.)
(A) Tests by Bureau of Steam Engineering
(B) Tests of Quasi-Arc System
(1) Tests by Machinery Division.
(2) Tests by Hull Division.
(3) Description of Outfit.

Report Number Twenty-One: Tests of Electric Arc Welding Carried Out in the Spring of 1918 at the Schenectady Works of the General Electric Co. (Pages 393-395.)

Report Number Twenty-two: Bibliography—This bibliography was prepared for me by Mr. John Liston, who, in this connection, obtained the co-operation of the various libraries of the General Electric Company.

[The 1918 section of this bibliography has been contributed by Prof. Bradley Stoughton.]

(Pages 397-418.)

Report No. 1

CONCLUSIONS WITH REFERENCE TO THE USE OF ELECTRIC WELDING FOR SHIP WORK

As a preface to my conclusions it is of interest to quote the following extract from a letter I have just received from a senior assistant at the Admiralty. Under date of 25th March, he states:

> "The electric welded barge at Richborough is progressing very successfully so far as welding is concerned. The entire work is expected to be complete within about 3 to 4 weeks, when tests will be made."

It may therefore be concluded that this barge is now complete and probably in service for cross channel work. Particulars of the vessel, in which no rivets have been used, are included in Appendix A of this report.

The flux-covered type of electrode has been employed throughout, the choice being made because of the very extensive use of this type of arc welding in England. In America the flux-covered type of electrode is rarely used and almost all American experience of arc welding relates to one or other of various systems employing Bare Metal electrodes. During my stay in America, I have made every effort to weigh the case as between the bare and flux-covered electrodes, but quite a number of factors enter into the problem, and I am not yet in a position to form any final conclusions as to the relative fields for these two systems. My general opinion, however, is that, as regards tensile strength, the two systems are much on a parity, but when it comes to bending and vibratory stresses, I should feel more confidence in welds made with flux-covered electrodes of approved quality and manufacture.

I am, however, now thoroughly satisfied that in the hands of skilled operators, good results can be obtained with either class of electrode provided direct current electricity is available. On the other hand, when it is desired to work from alternating current systems without the use of converting apparatus, it is necessary to employ flux-covered electrodes in order to obtain the best results. Although in the course of my very exhaustive investigations here in America I have seen a great deal of excellent work done with the bare metal electrode, I should personally prefer to employ the flux-covered electrode in any work in which I considered it important that the very best possible results should be secured.

In Britain all plans for the application of electric welding in ship construction involve the use of the arc system. This is largely due to the difficulty in obtaining materials required for spot welding machines and the delay in delivery of these, which precludes spot welding from being employed to carry out such operations in this time of emergency and urgent necessity. In America, on the contrary, a good deal of interest is shown in the possibility of applying spot welding to a good many parts of ships and several welding specialists even go so far as to express great confidence in the use of spot welding in combination with arc welding to join hull plates. British shipbuilders will be much interested to know that spot welding has been worked out to a point in America where it can be employed with the certainty of obtaining good results in various kinds of ship work, such as in the fabricating of frames, bulkheads, skylights, tanks and ventilating ducts. Spot welding, when applied to watertight junctures, should be supplemented by arc welding.

However, my personal opinion based on a most thorough investigation is that by far the greatest amount of shipwork will be done by arc welding. While my perusal of available tests of arc welding with bare metal rod electrodes, satisfies me that joints made in this manner will withstand tensile and compressive stresses fully equal to similar riveted work, I have not yet been able to satisfy myself as to the conclusiveness of available tests in which samples made with bare metal electrodes were bended through any considerable angle, whilst I have no information of vibratory tests having been carried out. But I know from my experience in England with work carried out by flux-covered electrodes that tough welds capable of satisfactorily withstanding severe bending stresses can be uniformly produced by capable operators, and this contention is supported by the results of tests carried out by the British Admiralty at Portsmouth (Vide Report No. 11).

It must be borne in mind that at present, arc welding specialists are not all in agreement as to the preferred composition of the electrodes for given purposes, consequently all sorts of grades of wire are in use and a great deal of the difficulty in drawing conclusions from test results arises from the considerable differences in the conditions under which the welds have been made. When approved electrodes are employed by skilled operators having the use of suitable circuit conditions as to steady voltage and appropriate voltage, and, of still greater importance, constant current of the correct amount for the size of the electrode and the character of the work, there is practically no liability of defective work. But I have encountered in America many instances of failure to give sufficient recognition to the importance of attention to all these factors, and I have seen that unsatisfactory results

have been the consequence. Moreover, in the application of electric welding to ship construction, it is of utmost importance that the work should be controlled not only in its broad outlines, but also in all its details by naval architects, marine engineers and shipworkers since it is only such men who are thoroughly acquainted with the many factors essential to success in these applications of electric welding. The best intentioned efforts of electric welding specialists without this ship experience, would, in my judgment, lead to failure and might discredit the entire proposition. On the other hand, in order to extensively employ electric welding in ship work it will be necessary to cut loose completely from many of the traditions and conventional practices whose raison d'etre arises from the detailed nature of the methods (such as riveting and forging) to which welding affords an alternative. It is difficult to accomplish this in existing shipyards and much more satisfactory progress can certainly be obtained in a shipyard specially designed and equipped for employing welding methods wherever these have been demonstrated to be the most appropriate.

Assuming that the necessary precautions are taken to minimize the difficulties that might be expected in the initial development of the electric welded ship, I am in entire agreemnt with the electric welding committee on the following points:

(1) That electrically welded ships can be built at least as strong as riveted ships;

(2) That ships designed to be riveted throughout can easily be so modified as to adapt them to extensive electric welding without departing appreciably from the use of materials originally required, with a considerable saving in cost and in the time required for hull construction; and

(3) That ships especially designed for electric welding can be built at a saving of 25 per cent in both labor and materials over present methods, and in less time. Moreover, a class of labor not now used for shipbuilding may be largely employed.

I heartily concur in the recommendations made by the Electric Welding Committee as follows:

(a) The modification of the design of a standard ship for the introduction of welding methods as far as may be consistent with the saving of time and without seriously affecting the materials now on order.

(b) The preparation of the design of a completely welded ship to the end that this method of construction may be utilized with the greatest gain in the saving of time, labor and material. The size of this ship to be such as is most useful at this time.

(c) The preparation of the plans and layout of a shipyard for the construction of ten of these ships.

An interesting demonstration of electric welding is contemplated by Mr. A. J. Mason, who, I understand, has arranged to completely weld the midship section of a 9500-ton standard ship at the Federal Shipbuilding Yard, at Newark. (Vide Report No. 4.) It is intended to redesign the structure and fittings suitably for electric welding, which, to my mind is of primary importance in order to obtain the best results from electrically welded work as regards strength, cost and saving of material and labor. Apart from certain initial mechanical difficulties, there is no reason why this section should not be satisfactorily complete to easily withstand hydrostatic pressure.

Considering the time involved in the carrying out of this demonstration, it is unfortunate that arrangements could not be made for the fore and aft sections to be completed by standard methods to permit of the vessel being tried out in service.

For embarking at once on a vigorous welding program, it is necessary to train large numbers of welding operators. I am advised that this situation is being given adequate attention and that plans have been made by Mr. E. E. MacNary for the training of large numbers of operators to meet future demands as found necessary. The Industrial Training Department, under the direction of Mr. MacNary, is establishing centers for training electric welding operators and demonstrating instructors. Shipyards throughout the country have been invited to send men to these centers, who, on completion of their period of tuition, will receive a bonus of $5.00 a day for each day's attendance at the centers.

As to material, arc welding requires a minimum of machinery and such as is necessary is available. Electrodes of various kinds can be provided in ample quantity.

Consequently, all that is necessary in order to embark upon the above indicated program is to authorize the work being carried out by qualified and responsible parties and to place suitable requisitions for materials and operators.

APPENDIX A

Description of Electric Welded Cross Channel Barge.

Particulars of this vessel which will be used in transporting material to France are as follows:

Type—Cross channel towing barge.

Deadweight, 200 tons.

Length between perpendiculars, 125′ 9″.

Breadth, moulded, 16′ 4″.

Depth, moulded, 7′ 9″, with sufficient deck curved stern with transom stern and two hatchways each 42′ x 10′.

Three bulkheads are fitted. The fore and aft bulkheads, being watertight, and one divisional bulkhead, watertight, in the middle of the hold.

The scantlings are as follows:

Frames, 2½″ x 2½″ x ¼″ steel angle.

Floors formed of 7″ x 3½″ x 7-20″ angles.

Shell and deck plating, $\frac{6\text{-}5''}{20}$

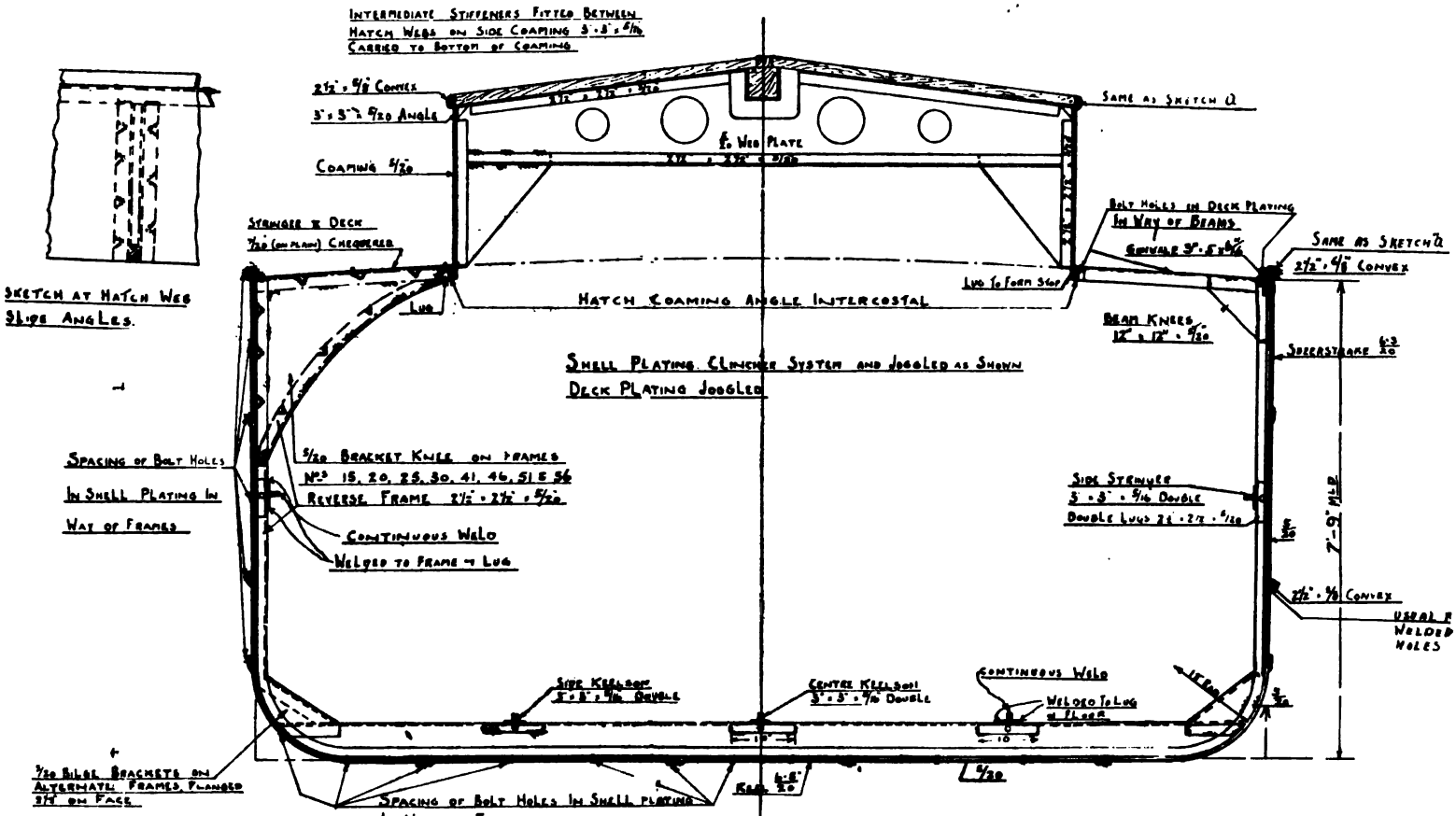
The vessel has a flat hull and four strakes of plating to each side. The flat edges of the shell plating are joggled.

The construction is generally similar to that of a vessel intended to be riveted up, the various pieces being held together in the first place by service bolts widely spaced, but sufficient to hold the surfaces together, in the case of the shell and deck plating the spacing being 10½″.

When the plates have been connected by the welding, the service bolts are removed and replaced by plugs and welded up flush with the plating, forming an additional connection between the two plates, plate and frame or whatever the case may be.

The frames are connected to the shell by the service bolts before mentioned, then tacked to the shell plating alternatively by the heel and toe. The service bolts are then removed and the holes plugged and welded up.

Other parts such as keelsons, hatch, coamings, brackets, lugs, etc., are similarly connected.


Intermediate Stiffeners Fitted Between Hatch Webs on Side Coaming 3"·3"·5/16 Carried to Bottom of Coaming
2½"·⅝" Covers
3"·3"·9/20 Angle
Coaming 5/20
Same as Sketch Q
Same as Sketch R
2½"·⅝" Convex
Bolt Holes in Deck Plating In Way of Beams
Stringer & Deck 7/20 (on flange) Chequered
Lug
Lug to form Stop
Hatch Coaming Angle Intercostal
Beam Knees 12"·12"·9/20
Sheerstrake 6'3 20
Shell Plating Clinched System and Joggled as Shown
Deck Plating Joggled
Sketch at Hatch Web Slips Angles.
Spacing of Bolt Holes In Shell Plating In Way of Frames
5/20 Bracket Knee on Frames Nos 15, 20, 25, 30, 41, 46, 51 & 56
Reverse Frame 2½"·2½"·5/20
Continuous Weld
Welded to Frame & Lug
Side Stringer 5"·3"·5/16 Double
Double Lugs 2½"·2½"·5/20
7'-9" M.L.R.
2½"·⅝" Convex
Useful & Welded Holes
Side Keelson 5"·3"·5/16 Double
Centre Keelson 5"·3"·5/16 Double
Continuous Weld
Welded to Lug & Floor
5/20
5/20 Bilge Brackets on Alternate Frames, Flanged 3½" on Face
Spacing of Bolt Holes in Shell Plating In Way of Frames

MIDSHIP SECTION OF CROSS CHANNEL BARGE

APPENDIX B

TITLE: Detailed Discussion of the Application of Electric Welding to Ship Construction.

The extent to which electric welding is applied to ship construction in Britain is fully described in the report prepared by Mr. H. M. Hobart, under date of December 10, 1917, and such additional applications as were developed prior to my sailing for America early in February, are included in Report (No. 11). Also a résumé of current British welding practice is to be found in a paper entitled "Notes on Welding Systems," which I read before the Institute of Engineers and Shipbuilders of Scotland on the 22d of January, 1918.

Electric Welding Systems

The systems of electric welding which are now being employed to a limited extent with every prospect of considerable further application in the fabrication of ships both in America and Britain are:

1—Resistance Welding, comprising (a) Butt, (b) Spot, (c) Line methods.

2—Arc Welding, employing either bare or flux-covered metal electrodes.

These several methods of welding are briefly referred to hereunder:

1—(a) BUTT WELDING (Vide Section C of Report Seventeen).

This method is applicable to the welding of rods, bars, etc., transverse to the length of the pieces. The pieces to be united are brought together end on, held in proper clamps connected to, or forming part of the transformer low pressure winding, the current is switched on, and end pressure is applied by ratchet or hydraulic gear as soon as the ends are sufficiently heated. The pressure and current are maintained until a distinct burr is formed round the weld, showing that an appreciable amount of plastic flow has taken place, and that there is little likelihood of any oxide, which may have been formed, remaining in a continuous formation to weaken the weld. This weld is in most cases hammered whilst cooling.

Butt welding is suitable for the joining of bars which constitute the longitudinal membe of a concrete ship, but the service applications in a shipyard are limited.

(b) SPOT WELDING: (Vide Report 9 and Section D of Report 17) has been largely used to unite sheets or thin plate where a continuous weld or joint is not required. The two sheets are placed between electrode clamps which press them together, current is then switched on and the surfaces in contact are brought up to a welding heat. The pressure is maintained after current is off until sufficient cooling occurs. The sheets are then moved on to the next spot to be welded, and the operation is repeated. Work so welded is therefore united by a line of small welds or spots, and may be compared to flush riveted work.

Further developments of this method, which comprise the "riveting" of much thicker plates as required for the hull of a ship, have, I understand, been successful in this country. (See Section D of Report Seventeen.)

It would appear that spot welding is eminently suited to replace riveting and caulking to a very large extent in the future.

(c) LINE WELDING: (Vide Section A of Report Seventeen).

ARC WELDING

It is of interest to note, that whereas arc welding with bare metal electrodes has been almost exclusively used in America, until quite recently, the flux-covered metal electrode has had most extensive use in Britain.

(a) With the bare metal electrode system of arc welding an arc is struck between a rod of metal and the work. The heat then generated at this point melts a small pool on the parts to be welded, and additional metal is deposited from the electrode in a molten state, thereby forming a firm union between the new and old metal, if certain precautions are adopted to ensure even application and the prevention of porous metal due to excess of current.

To prevent oxidation the metal rod is sometimes coated with a flux which decomposes with heat and surrounds the molten metal with an inert gas.

(b) The flux-covered electrode system of arc welding most commonly used provides for the metal electrodes being encased in a flux composition which becomes molten at the arc so that the added metal is at no time exposed to oxidation. When properly applied, this flux forms a silicate slag of suitable viscosity which floats on the metal surface until removed when cold by tapping with a small hammer and using a wire handbrush. Arc welding, whether carried out with bare or flux-covered electrodes, has a wide application to ship construction and repair.

(c) The art of arc welding with a carbon electrode preceded by several years the commercial introduction of the metal electrode. It consists in supplying the heat with the arc estab-

lished between a carbon electrode and the work, and thereby welding together the material on the two sides of the joint or else introducing additional material by means of a pencil, the tip of which is projected into the arc and thereby melted. The use of the metal electrode has by no means superseded the carbon arc method, the latter having a wide field of its own. In Report A of Section 17 will be found a number of photographs of automatic machines for welding by the carbon electrode system and of commercial welds made by this system.

RELATIVE SUITABILITY OF EACH SYSTEM OF ELECTRIC WELDING TO SHIP WORK

For the carrying out of spot welding alternating current is necessary. The supply voltage is immaterial as a transformer forms part of each machine. With spot welding it was understood that metal adjoining the weld became very brittle when subjected to vibratory stresses, the line of jointure between plates containing a layer of oxide which considerably weakened the weld, and difficulty was experienced in obtaining sufficient adhesion. I am informed that with recently developed machines provided with gear to give sufficient pressure to close the plates and by the use of increased current, the latter difficulties have been overcome, whereas it is stated that crystallization does not occur to any appreciable extent with thick plate work. It may therefore be assumed that spot welding is in a fair way to replace largely, if not altogether, the riveting and caulking methods of joining ship fittings and plates.

A spot welding machine suitable for thick plates is a heavy tool weighing several tons, and it would therefore appear that it will be most efficiently employed as a stationary plant. It is therefore recommended that in the first instance spot welding be used for the fabrication of internal ship parts. Spot welding work may be made more or less watertight by reducing the spacing of the spots even to the extent of making adjacent welds overlap. An objection of this method being applied to the welding of long lengths of plating such as are met with in the hull of a ship, is that distortion will result due to the heat generated for quite a considerable distance from the weld unless allowance is made to counteract the expansion and contraction. When spot welding bulkhead plates and framing it is advisable for this reason to weld alternate spots in one operation, then traversing the work again to complete. Additional electrical energy will be necessary by

the adoption of this means, but to my mind the assembled parts will be more accurate. The combined used of spot and arc welding is referred to hereafter.

ARC WELDING: No sweeping decision can be made as to the relative merits of arc welding by means of bare and flux-covered metal rod electrodes. There are certain conditions that seem to preclude universal adoption of any one of these methods, and hereunder I propose to refer briefly to circumstances that affect the choice:

ELECTRICITY SUPPLY:

Direct Current: Both bare and flux-covered metal electrodes are effective with direct current supply, provided the voltage and current at the arc is kept within the desired range. To obtain a reduction in the line voltage a motor generator or rotary balancer must be employed.

Alternating Current: Bare metal electrodes are not now suitable for use with alternating current, although there are certain investigations afoot, such as the "Holslag" transformer, that would seem to make it possible to use bare electrodes A. C. supply. The results obtained with flux-covered electrodes are, however, quite satisfactory. With the latter the supply may be taken direct to the arc through a "Holslag" transformer or 110 volts may be obtained with a static transformer, the current regulation at the arc being maintained by a regulating resistance in series.

RELATIVE CONDITIONS:

As regards the respective merits of bare and flux-covered metal electrodes for arc welding, apart from electric supply conditions. Consider these below:

Tensile Strength: There is no reason why a correct weld by either method should not be made to approach the strength of the original plate.

Toughness: By virtue of the annealing properties of the slag and the absence of oxidation in added metal, the flux-covered electrode is superior.

Quality of Metal: The flux may be made the vehicle of constituents which will give desired characteristics to the added metal. Porosity or piping will also be reduced by the use of flux-covered electrodes.

Cost of Power and Equipment: The bare metal electrode is the cheaper if connected direct to the general electric supply system. It is, however, more usual practice in America to provide an auxiliary machine with substitutional resistance or other regulating features

to give the correct current at the arc, whereas with flux-covered electrodes no such refinement is necessary.

The power required and the cost of the equipment vary with the number of welders in use, the character of the work and the method employed. The larger the number of welders in simultaneous use, the more closely the total power needed will approximate to the sum of the averages, so that installations providing for many welders are relatively less costly in regard to power plant than small installations with only a few welders.

Welding Versus Riveting: Such particulars as are available for intelligent comparison are included in Report Eleven. By eliminating the routine of marking off, punching reaming, caulking, to say nothing of the planed butt straps and insertions at watertight joints, there is ample margin to cover similar construction by means of electric welding until the process is standardized when costs would be further reduced.

The most important point in favor of extending the use of electric welding is the reduction in amount of labor (Vide Report 11) which would be at least 25 per cent of the present charge under this head. Furthermore, superfluous material in the form of overlapping riveted plates and of angles and brackets would be considerably reduced.

Report No. 2

TITLE: Brief Chronological Record of My Visits.

(This constitutes a key to my subsequent reports, reference to each of which is introduced at its appropriate place.)

Accompanied by Sapper J. M. Muir, I left the Admiralty, London, first of February, to proceed to America for duty with the United States Shipping Board Emergency Fleet Corporation.

Due to unavoidable circumstances, our arrival in this country was delayed until the evening of 16th February, when we were met on arrival by Messrs. E. A. Stevens, Jr., representing the Emergency Fleet Corporation, and H. M. Hobart, who had kindly made arrangements for our accommodation at New York.

Descriptive notes of my several visits to shipbuilding yards, etc., are included in Report Number Three.

On the 21st of February I visited the Submarine Boat Corporation, Newark, N. J., who showed special interest in electric welding (Vide Report No. 3-A). It was at that time under consideration that this firm should be entrusted with the construction of an electric welded midship section of a 5,000-ton standard ship, similar to the undertaking referred to in Report No. 1.

In the afternoon I proceeded to Philadelphia, where I met Rear Admiral Francis T. Bowles, and his assistant, Mr. E. E. MacNary. It was then suggested that an organization would be established at Philadelphia to arrange for the training of welding demonstrators to instruct unskilled labor at the Hog Island Shipbuilding Yard of the American International Shipbuilding Corporation (Vide Report No. 3-T).

Accompanied by Mr. E. A. Stevens, Jr., I then proceeded to Washington and called on Mr. D. H. Cox, Manager, Division of Steel Ship Construction, when a tentative program was prepared of my future movements. I thereafter visited Captain Stocker and Commander Land, at the Navy Yard offices, to discuss recent electric welding developments in Britain, and arranged for attendance at such navy yards in this country as time would permit (Vide Report No. 3-J and R).

I visited the Baltimore Drydock and Shipbuilding Company, Baltimore, on the 23d February, where I had a

most interesting meeting with Mr. H. A. Evans, President. (Report No. 3-C.) This, I consider one of the best laid-out shipyards I visited, and the management indicated that they were most anxious to make full use of electric welding, which has only been previously used by them to a very limited extent in their drydocks.

On the 24th of February I had a further meeting with Admiral Bowles and Mr. MacNary, arranging the scheme proposed to be set up for the instruction of welding operators, and assisting in the preparation of circulars and technical data to be used for instructional and publicity purposes.

At Schenectady, on the 25th, 26th and 27th of February, I attended the works of the General Electric Company. In addition to having several matters of interest explained to me by officials and engineers, arrangements were made for the carrying out of welding tests to demonstrate the relative merits of bare and flux-covered metal electrode systems of electric welding, and Sapper Muir remained to carry out this work. I was particularly interested to witness the tests which were carried out in my presence, of a spot welding machine which the General Electric Company had recently developed for the joining of heavy steel plates (Vide Report No. 17, Section D). Other matters discussed with me were as under:

Mercury Boiler and Turbine Unit
Eectric Marine Propulsion
Cast Steel Anchor Chains

I traveled to Pittsfield on the 28th of February to inspect the Pittsfield Works of the General Electric Company. Electric arc welding was being used extensively in the manufacture of transformer tanks, and I understand a saving in cost amounting to 10 per cent had been effected due to the introduction of the bare metal electrode arc system. A full description of the welding activities at Pittsfield is given in Report 17, Section A.

At New York on the 4th of March, I called on Mr. E. B. Katte, Chief Engineer of the New York Central Railroad Company, and I also met his assistant, Mr. Holslag, who was responsible for the electric welding carried out by the New York Central Railroad. It was stated that electric arc welding with bare electrodes had been extensively applied in the repair of rolling stock at all the N. Y. C. shops. Comprehensive data of work done with different American machines and types of electrodes were shown. I am pleased to be able to include these particulars, with other information since supplied to me by Mr. E. B. Katte in Report No. 8.

In the afternoon I attended the Emergency Fleet Corporation offices, 115 Broadway, New York, where I met Mr. A. E. Wilkie and other members of the staff. My time was spent with Messrs. Rushmore, Stevens and Hobart during the after-

noon of the 4th of March, discussing future plans. Later in the afternoon I called at the British War Mission, and the Inspector Department of the British War Office.

Staten Island Shipbuilding Company, New Brighton, N. J., was visited on the 5th of March, when I interviewed Mr. Bates, Vice President. I found that electric welding had been applied to a limited extent for repair work by means of portable welding machines. (Vide Report No. 3-D.)

In the afternoon I visited the Standard Shipbuilding Company, when I had an interesting meeting with Mr. E. Godoy, General Manager, and other members of his staff. No electric arc welding has been carried out at this yard, but trials have been made to heat rivets electrically and a spot welding machine has been installed for the manufacture of steel templates. Mr. Scott, the Chief Engineer, supplied me with the cost of riveting, etc., with pneumatic plant, which indicated that electric welding could be used to advantage (Vide Report (No. 3-E).

On March 7th, I visited the Federal Shipbuilding Company and was shown round the plant by Mr. R. McGregor, who appeared to be in favor of electric welding, as he had recently ordered five equipments from the Quasi-Arc Company, and a spot welding machine from the Universal Welding Company of New York. (Vide Report No. 3-F.) I have since been informed that the midship section of a 9,500-ton ship is to be constructed entirely by means of electric welding at this yard, when it is intended to try out several systems available and alter the design of structural parts suitable for welding. (Vide Report No. 1, Appendix B.)

This afternoon I had a meeting with the directors of the Quasi-Arc Weltrode Company and visited their works to primarily ascertain the possible output of electrodes in view of the increased demand for electric welding. The firm promised to make every endeavor to deal energetically in this matter, and I was pleased to learn that arrangements were in progress for the extension of their manufacturing capacity (Vide Report No. 3-G), and facilities were being provided for the training of operators.

The Moore plant of the Bethlehem Steel Corporation at Elizabethport, and Downey's Shipbuilding Corporation were visited on 8th March. Electric welding has not been used at the former plant, but Mr. Bursh, the shipyard Manager, was very interested in recent developments and suggested that I should recommend the adoption of welding construction to one of the 20 tugs now building at this yard (Vide Report No. 3-H).

At Downey's I saw good electric welding work being carried out by Mr. Fred Tye, who was a most efficient operator with both bare metal and and flux-covered electrodes,

although it is a matter of regret that the plant at his disposal was not very suitably planned, and welding work appeared to be confined to repairing machine tools and shop plant. (Vide Report No. 3-I.)

At the Brooklyn Navy Yard I spent all day of the 9th March. In addition to meeting the several officers indicated in Report No. 3-J, I was shown the electrical equipments in use and the comprehensive work on which they were engaged in the several divisions of this navy yard.

Along with Lieutenant Kramer, I also inspected the S. S. Princess Irene, which was of special interest in view of the repairs carried out to the damaged machinery of this commandeered German vessel, which had since been engaged in European transport service. The Chief Engineer informed me that no trouble had been experienced with the engine parts repaired by electric welding, with the exception of a leak at the welded juncture of the high pressure cylinder, which was due to there being a space between the top of the liner in this cylinder and the cover.

On the 3d of April, along with Messrs. Stevens and Hobart, I visited the Quincy Shipyard of the Fore River Shipbuilding Company. Mr. E. H. Ewertz, the General Superintendent of this Company, has been interesting himself in the application of electric welding to ship construction for some considerable time. He explained his proposals (1) for the entire electric welding of a torpedo boat; (2) a cargo vessel, and (3) a barge 300 feet long, all of which contained features of special interest. Mr. Ewertz appeared to have become convinced as to possibilities of electric welding after having carried out tests on a welded submarine tank which he subjected to 180 pounds pressure, when the welded joints proved satisfactory, although the side plating of the tank was displaced. I have described in Report No. 5 Mr. Ewertz's type of electrically welded ship. Mr. W. L. Roberts, who is in charge of the welding work at this yard, supplied me with relative data which he had collected (Vide Report No. 3-K).

The River Works of the General Electric Company at Lynn was visited on 19th March, where it was noted that electric arc welding with bare metal electrodes was used to a very limited extent. (Vide Report No. 3-L.)

I also visited Professor Elihu Thomson at his laboratory and later at the works of the Thomson Welding Company, where I witnessed the operation of a bull riveter machine recently converted to operate as a portable spot welder. (Vide Report No. 3-M.)

The shipyard of Messrs. William Cramp & Sons was visited on 21st March, along with Messrs. Adams and Stevens. Considerable use has been made there of electric welding by means of the carbon arc to replace smith welding in the con-

struction of ship fittings (Vide Report No. 3-N). Simplified designs of the structures have been prepared and issued to the workmen, who receive special inducements to increase output. I was especially impressed with the average performance of the riveters at this yard, as borne out by the statement of costs covering a considerable period. It may be mentioned here that Mr. Mull, President of the William Cramp & Sons Ship and Engine Building Company, and a Naval Constructor whom I met at another yard, are the only responsible parties interested in ship construction who have expressed strong views against the necessity of introducing other methods than riveting and caulking for the joining of hull plates. Mr. Mull further stated that at present riveting presented no difficulties as regards the obtaining of sufficient skilled riveters.

At Philadelphia on 22nd March I met Mr. W. T. Bonner, who explained to me his various activities in electric welding during the last three or four years, and also showed me numerous photographs and descriptions of his work (Vide Report No. 7). Thereafter I accompanied Mr. Bonner to the Chester Shipbuilding Company (Vide Report No. 3-O), where several welding equipments are in use for the construction and erection of ship fittings, and I was also shown an electric welded model section of an oil carrying barge partially constructed by Mr. Bonner.

The electric welding work being carried out at the West Albany Shops of the New York Central Railway Company was of special interest in that I was able to inspect the Holslag static machine for use with alternating current supply, and appreciate the satisfactory results obtained by Sapper Muir with this machine. (Vide Report No. 3-P and Report No. 10.)

On 27th March I visited the Newport News Shipbuilding and Drydock Co., along with Messrs. Adams, Stevens and Hobart. It was noted that electric arc welding with bare metal electrodes had been extensively adopted at this yard and in addition to much oxy-acetylene welding, considerable good work had been done under the supervision of Mr. H. I. Walsh and his staff of 125 operators in various stages of proficiency. In addition to the existing equipment, I was informed that apparatus suitable for flux-covered electric arc welding had recently been ordered. Indications are given in report No. 3-Q of the extensive repair work carried out by welding at this yard, but apart from the further extension of the process on this class of work, there would appear to be considerable potentialities for the substitution of electric welding for riveting in new work. It is of interest that 17 damaged German liners were repaired here. It was at first intended to execute these repairs by means of electric welding cast steel patches to the iron castings. Subsequently, however, acetylene welding with

cast iron filling rod was employed for the carrying out of these cast iron repairs.

At Portsmouth Navy Yard at Norfolk, I was received by Naval Constructor Watt and Naval Constructor Knox. In the shops, electric spot welding has been successfully applied and three machines are in constant use, in addition to 17 electric arc welding equipments including Wilson, C & C and Quasi-Arc. I also inspected an automatic machine for the electric welding of the circumferential seams of Mines. It was stated by Naval Constructor Knox that by the use of this machine even in its present undeveloped condition, the seam around the Mine could be welded in 15 minutes instead of 60 minutes, as taken by the hand operators at present. (Vide Report No. 3-R.)

Mr. H. M. Hobart accompanied me to the New York Shipbuilding Company on 3rd of April. This visit was of special interest in view of the spot welding investigations carried out by this firm sometime ago (Vide Report No. 9 and Report No. 3-S), also because we were able to inspect a watertight door with parts assembled with a combination of spot and arc welding. Only one arc welding machine is at the present time in service with bare metal electrodes. At the request of the management, I sent Sapper Muir to give a demonstration of electric arc welding with the flux-covered metal electrode.

I was very much impressed with my visit to the Hog Island Shipyard of the American International Shipbuilding Corporation on 4th April (Vide Report No. 3-T). Four spot-welding machines have already been ordered, capable of joining heavy fabricated parts. Equipments by various makers of electric arc welding apparatus are being installed for the instruction of skilled operators in all systems to meet the anticipated demand for these from shipbuilding concerns all over the country.

On behalf of the British Admiralty, I visited the National Malleable Castings Company's shops at Sharon and Cleveland on the 9th of April, to investigate the extent to which this firm would be in a position to apply cast steel anchor chains (Vide Report No. 3-U).

Along with Messrs. Adams, Stevens and Rigby, I attended at the works of the Ford Motor Company on 10th April. (Vide Report No. 3-V.) We were received by Mr. W. S. Knudson, Supt. of Construction, who explained the design and proposed method of constructing the novel type of Submarine Chaser, the parts for which it is intended to manufacture at the factory, whilst erection will be carried out at the new shops now in process of erection at River Rouge. One General Electric and two Wilson machines were on order. It is intended that these will be used with bare metal electrodes, but I understand that Mr. Knudson is now arranging to carry out

trials with flux-covered electrodes. No indication was given as to the extent to which it was proposed to adopt electric welding in the construction of the submarine Chaser Craft.

This report was forwarded to Mr. D. H. Cox, Manager Division of Steel Ship Construction at the Washington offices of the Emergency Fleet Corporation on April 22nd. Thereafter I propose to assist the Electric Welding Committee to develop their plans for electric welded ship construction, until 30th April, when I terminate my period of duty with the U. S. Shipping Board.

It is also intended to visit Schenectady to witness the completion of the tests being carried out under the direction of Mr. E. E. MacNary and myself, and if possible, I will render preliminary assistance to the Ordnance Department, from whom I have received advice that application has been made to the British Admiralty for my services for a period not exceeding one month.

APPENDIX A

Four District Meetings to Discuss Welding

In addition to attending the several meetings of the Electric Welding Committee at New York, (Vide Report No. 4), I was present at meetings of shipbuilders and local representatives of the Emergency Fleet Corporation and Classification Societies held at various centers as under:

March 18, Boston, Mass.
21, Philadelphia.
26, New York.
29, Baltimore.

These meetings were held for the purpose of enabling me to meet and confer with a larger number of men in the shipbuilding and allied industries than would otherwise have been possible. The attendance is indicated on the attached sheet.

Professor Comfort A. Adams, Chairman of the Electric Welding Committee, presided on all these occasions and after himself reviewing the situation called upon me to describe the nature and purpose of my mission. The following resolutions passed at the Boston gathering are typical of the views held by all the interests represented at the above meetings:

WHEREAS being convinced that a considerable saving in time and material can be brought about by the introduction of electric welding in shipbuilding—be it—

RESOLVED: That the Emergency Fleet Corporation be urged to authorize its committee on electric welding to prepare immediately a modification of the plans of a standard ship, to the end that it may be most readily assembled by electric welding.

Also, that the Emergency Fleet Corporation be urged to authorize the construction of such a ship, electrically welded throughout, work to be started as soon as the plans are completed.

Also, that in the meantime electric welding be applied as rapidly as possible to those parts of ships now under construction, where the greatest saving of labor and material is obvious.

Also, that the Training Department under Mr. MacNary be authorized to make plans for the training of three thousand (3,000) arc welders within the next three months

March 18, 1918.

List of Those Who Attended the District Meetings.

(1) Representatives of Emergency Fleet Corporation.

Prof. C. A. Adams,
Chairman, Electric Welding Committee.
E. A. Stevens,
Secy. Electric Welding Committee.
H. M. Hobart,
Member, Electric Welding Committee.
E. E. MacNary,
Industrial Training Department.
A. E. Wilkie,
District Officer, New York.
J. S. Abrams,
Chief Inspector, New York
A. G. Volck,
Plant Engineer, New York.
H. O. Trowbridge,
District Officer, Boston, Mass.
H. I. Cole,
Resident Inspector, Quincy, Mass.
R. J. Drum,
Resident Inspector, Groton, Conn.
Edmund P. Briggs,
Resident Inspector, Texas S. S. Co., Bath, Me.
Joseph B. Rowen,
Resident Inspector, Portsmouth, N. H.
S. G. Jenks,
District Officer, Baltimore, Md.
D. G. Anderson,
District Supervisor, Baltimore, Md.
C. D. Albert,
Field Inspector, Baltimore, Md.
F. Walsh,
District Inspector, Philadelphia, Pa.
F. W. Grogan,
District Officer, Philadelphia, Pa.
Thos. M. Fendall,
Asst. Resident Engineer, Philadelphia, Pa.
Henry M. Wesson,
Inspector, Philadelphia, Pa.
J. Thornton,
District Officer, Philadelphia, Pa.
R. E. Armstrong, Inspector,
Pennsylvania & New Jersey Shipbuilding Companies, Philadelphia, Pa.

(2) Shipbuilders, Engineers, etc.

G. Norman Scott,
Standard Shipbuilding Corporation, New York.
Harold P. Brown,
Manager, Concrete Atomizer Co., New York.
Herbert M. Williams, President,
Bayles Shipyard, Inc., New York.
W. H. Hoab,
Todd Shipyard Corporation, New York.
Luther D. Lovekin,
American International S. B. Corp., New York.
John H. Anderton,
American International S. B. Corp., New York.
A. E. Van Bibber,
American International S. B. Corp., New York.
A. H. Ranger,
Bethlehem Shipbuilding Corporation, New York.
Robert Dowling,
Staten Island Shipbuilding Co., New York.
A. Cyril Rimmer,
Federal Shipbuilding Co., New York.
James A. Mitchell,
Newburgh Shipyards, Inc., New York.
R. C. Hodges,
Newburgh Shipyards, Inc., New York.
Clifton Yoemans.
Naval Architect, New York.
E. J. White, Supt.,
Atlantic Corp., Portsmouth, N. H.
E. H. Ewertz, Gen. Supt.,
Victory Plant, Bethlehem S. B. Co., Quincy, Mass.
H. B. Andrews, Supt.,
Virginia S. B. Corp., Alexandria, Va.
Thos. S. McElroy, Supt., South Yard,
Baltimore Dry Docks & S. B. Co., Baltimore, Md.
C. W. Lampole,
Virginia Shipbuilding Corp., Alexandria, Va.
C. M. Hensen, Bethlehem Shipbuilding Corp.,
Sparrows Point Branch, Sparrows Point, Md.
C. D. Hubbard, Bethlehem Shipbuilding Corp.,
Harlan Plant, Wilmington, Del.
James G. Dudley, Research & Experimental Dept.,
Chester Shipbuilding Co., Philadelphia, Pa.
F. P. Hall, Chief Estimator,
Chester Shipbuilding Co., Philadelphia, Pa.
H. A. Hornor, Consulting Engineer,
Hamilton Court, Philadelphia, Pa.

Joshua W. Atlee, Asst. to Naval Architect,
Wm. Cramps & Sons, S. & E. Co., Phila., Pa.
Edgar P. Trask, Asst. to Naval Architect,
Wm. Cramps & Sons S. & E. Co., Phila., Pa.
G. A. Pierce,
Wm. Cramps & Sons S. & E. Co., Phila., Pa.
H. C. Towle, Asst. Manager,
New York Shipbuilding Co., Philadelphia, Pa.
Wm. T. Bonner,
Chester Shipbuilding Co., Philadelphia, Pa.
Henry Thomas,
Sun Shipbuilding Co., Philadelphia, Pa.
J. W. Winston, Asst. Mgr. of Construction,
Sun Shipbuilding Co., Philadelphia, Pa.
Charles Morris, Supt. Mech. Dept.,
Sun Shipbuilding Co., Philadelphia, Pa.
Arthur Parker, Electric Engr.,
New York Shipbuilding Co., Philadelphia, Pa.
Walter Jones, Research & Experimental Dept.,
Chester Shipbuilding Co., Philadelphia, Pa.

(3) Classification Societies.

H. C. E. Meyer,
American Bureau of Shipping, New York.
Geo. C. Sharp,
American Bureau of Shipping, New York.
J. French,
Lloyds Register of Shipping, New York.
H. J. Cox,
Lloyds Register of Shipping, New York.
Peter Hynes,
Groton Iron Works, Groton, Conn.
F. O. Percy, General Mgr.,
Cumberland Shipbuilding Co., So. Portland, Me.

(4) United States Navy Department and Admiralty.

Captain James Caldwell, R. E.
Deputy Asst. Director of Materials and Priority,
Admiralty.

Report No. 3

NOTES RELATING TO EACH OF THE SHIPYARDS AND PLANTS VISITED

GENERAL HEADINGS.

(1) Date of Visit.
(2) Officials Interviewed.
(3) General Remarks.
(4) Method of Construction.
(5) Workers.
(6) Capacity.
(7) Output.
(8) Electric Welding.
(9) Conclusions, etc.

Report Number Three

1. List of Visits and Dates.
(Feb.-April, 1918.)

A—Submarine Boat Corporation (Feb. 21)....page 37
B—Concrete Boat Corporation (Feb. 22).....page 38
C—Baltimore D. & S. B. Corp. (Feb. 23).....page 39
D—Staten Island S. B. Co. (March 5).....page 41
E—Standard S. B. Co. (March 5).....page 42
F—Federal Shipbuilding Co. (March 7).....page 43
G—Quasi-Arc Weltrode Company (March 7)..page 44
H—"Moore" Plant, Bethlehem S. C. (March 8).page 45
I—Downey Shipbuilding Corp. (March 8)...page 46
J—Brooklyn Navy Yard (March 9).....page 47
K—Fore River Plant, Bethlehem Shipbuilding Corp. (March 16) .....page 48
L—"River Works" of Gen. Elec. Co. (Mar. 19)page 50
M—Thomson Elec. Weld Co. (March 19)....page 50
N—Wm. Cramp & Sons (March 21).....page 51
O—Chester Shipbuilding Co. (March 22).....page 53
P—West Albany Shops of N. Y. C. R. R. (Mar. 25) page 54
Q—Newport News S. B. & D. D. Co. (Mar. 27).page 55
R—Norfolk Navy Yard (March 28).....page 57
S—New York Shipbuilding Corp. (April 3)....page 59
T—Hog Island Shipyards of American International Shipbuilding Co. (April 4) .....page 60
U—National Malleable Castings Co (April 9).page 61
V—Ford Motor Co. (April 10) .....page 62

THE SUBMARINE BOAT CORPORATION (A)

Visited:
21-2-18. Accompanied by Messrs. Hobart and Rushmore.

Location:
Port Newark Terminal, Newark, N. J.

Officials Interviewed:
Mr. Henry Sutphen, Vice President.
Mr. B. L. Worden, General Manager.
Mr. C. T. Henderson, Engineering Manager.

General Remarks:
This yard is an offshoot from the works at East London, Conn., which is confined to the manufacture of submarines. It is laid out on marshy flat ground where operations were started in September 1914. Twenty-eight slips have now been laid down and the necessary offices and shops are nearing completion.

Methods of Construction:
Materials for ship construction will be delivered ready for erection on site, from 47 Fabrication Shops.

Workers:
18,000 to 21,000 men will be ultimately employed.

Output:
140 5,000-ton standard ships to be delivered within two years.

Electric Welding:
A spot welding machine has been ordered from the Universal Electric Welding Corporation (the total weight not to exceed 6 tons). It was pointed out to the firm that arc welding was more suitable for hull plating work and the suggestion made to use the spot machine only to hold plates in position during assembly, thereby replacing service bolts or wide spaced rivets, the difficulty of "bolting up and reaming" being thus obviated. Arc welding with bare electrodes (35 volts) has been tried. Sample welds inspected, although considered satisfactory by management, were of poor quality. This firm is most anxious to install extensive electric welding equipments. As a preliminary it is proposed to weld deck structures and an engine room compartment in yard to be used for fitting

pipes, etc., preparatory to fixing these in vessels. Later, with concurrence of Admiral Bowles it is desired to build an entirely electric welded ship. Mr. Henderson, who was most interested in this proposition, is now free to devote himself to the supervision of electric welding developments as his present work is sufficiently forward to provide him with the time.

CONCRETE BOAT CORPORATION (B).

Visited:
22-2-18.

Officials Interviewed:
Mr. E. J. Wig, Chief Engineer for Reinforcement Ship Flotilla, Washington, D. C.

General Remarks:

Methods of Construction:
(1) Straight framing.
(2) Isherwood.

Output:

Contracts placed:	Contracts dependent on successful completion:
(a) One, 7,500-ton vessel	(a) Five, 4,500 ton vessels.
(b) One, 3,000-ton vessel	(b) Forty-nine 3,000-ton vessels
(c) Two, 3,500-ton vessels	(c) Fifteen, 3,500-ton vessels

Application:
Standard Ships, Dry Docks, etc.
(Ideal construction:—concrete below water line, steel above. All concrete structures in sea water deteriorate when exposed to air due to concentration of sea salts.)

Electric Welding Uses:
(1) Longitudinal members, the length of ship.
Generally 1 to 1¼" diameter bar.
To be butt welded before fixing in position.
(2) Vertical and Diagonal Members.
⅜"x⅜", ½"x½" or ⅝"x⅝" section.

To be fixed (by welding), at intersections and to longitudinal bars.

Present proposal, to order two trial welding machines.

(a) One for Butt connections (Longitudinals).

(b) One for Lap connections (Verticals to Longitudinals).

Total number of machines required, 20 to 30.

Steel Work:—details.

Quality of steel, 60,000 lbs. tensile strength.

Factor of safety-2-until elastic limit reached.

Factor of safety-4-until fracture would occur.

Total Stress (local and longitudinal) calculated:

(a) Interior of Frames, 20,000 lbs. per square inch.

(b) Upper plating and Decks, 16,000 lbs. per square inch.

(c) Bottoms, 12,000 lbs. per square inch.

THE BALTIMORE DRYDOCK & SHIPBUILDING COMPANY, BALTIMORE, MD. (C)

Visited:

23-2-18. Accompanied by Mr. Stevens.

Location:

Baltimore, Md.

Officials Interviewed:

Mr. H. A. Evans, President.
Mr. H. M. Willis.
Mr. MacElroy, Supt. Steel Construction.
Mr. Adams, General Works Superintendent.

General Remarks:

Three years ago this firm carried on ship repair business with 25 men. They are now an extensive shipbuilding concern.

Methods of Construction:

Materials are finished on site with the exception of some standard detail fittings. It is not intended to build ships with fabricated parts at this yard.

Workers:

25 men—3 years ago.
4,500 men—At present.
6,000 men—Shortly.

Capacity:

Two Dry Docks.
Two slips (220 yds.) Old Yard.
Six slips (440 yds.) New Yard.

Output:

Old Yard put into service 12 months ago. Conditions most inefficient.

7—5,000-ton ships (cargo and mine sweepers) completed.

New Yard to be completed March 1918.

18—10,000-ton ships per annum, each 70 days in slips
50 " fitting out
—
120 days total

Typical contract just placed by Emergency Fleet Corporation. 10—10,000-ton Tankers to be delivered October 1918.

New Yard layout arrangement—So arranged to facilitate handling of materials which will pass through the shops without interruption.

Sequence:

(1) Railway Siding.
(2) Store Yard—Capacity 20,000 tons.
Plates on edge.
(3) Covered Shop (a) Plate Rolls.
(b) Punches
(Mech. moving table on rollers operated by one lever.)
(4) Traveller roller supports on rails.
(movement straight forward or across shop.)
(5) Outside Transverse Crane.
(6) Two Derrick Cranes between each slip for forward movement of material.
(7) Space between shop and slips 120 yards.
(8) Two Piers 1,100 ft. long either side of 6 slips.
(9) Outfitting Piers (a) Boiler shop at end of No. 1.
(b) Carpenters and Outfitting shops.
(c) Stores for completed fittings awaiting launching.

Electric Welding:

Formerly used for Boiler repairs, etc., which were executed by Maryland Welding Company, Baltimore. Interviewed Mr. Davis of this Company who stated:

(1) Bare rod and gaseous flux electrode used.
(2) Compound wound portable Machine 40/60 volts D. C. Voltage of arc does not exceed 30 volts

(3) Does not preheat Cast Iron work (sometimes successful).

This firm is alive to the possibilities of electric welding. They propose to install plant with a view to assembling bulkheads and deck fittings. It is also proposed to consider spot welding for fabricated structures.

Conclusion:

The New Yard is the most efficient installation I have ever seen and should certainly give most expeditious production.

Criticisms:

The Shop Plant seems large for the number of slips laid down. It was noted that considerable difficulty was experienced at the drydocks due to freezing of the river. The drydocks were inadequate to cope with the repair work requiring attention (15 vessels awaiting entry during my visit).

STATEN ISLAND SHIPBUILDING COMPANY (D)

Visited:

5-3-18. Accompanied by Messrs. E. A. Stevens and H. M. Hobart.

Location:

Staten Island, New York.

Officials Interviewed:

Mr. Bates, Vice President (Technical).

General Remarks:

Methods of Ship Construction:

All the work of fabrication is carried out locally.

Workers:

New yard started a year ago—1,000 men.
Old yard for repairs only—1,000 men.

Capacity:

New yard 6 slips 300 feet long 2 drydocks.
Old yard 3 drydocks.

Output:

3,500-ton cargo vessels.
8 mine sweepers for U. S. A. Navy Dept. and sundry tanks.
Each 90 days in slips 50 to 60 days fitting out.

Electric Welding:

Equipment:

2 Wilson machines on trolleys, 20 to 25 volts.
1 C. & C. machine, 70 volts.
Each suitable for one welder. They repaired two of the damaged German ships, including the cylinders 70" in diameter, 5' stroke. The cast steel patches were welded to the cast iron cylinders, both of these having steel studs. These cylinders were fitted with flange liners. The cost of repairing each cylinder was approximately $7,000. The electric welding of brass is carried out successfully at this yard with the welding machines using bronze electrodes.

STANDARD SHIPBUILDING COMPANY (E)

Visited:
5-3-18. Accompanied by Mr. H. M. Hobart.

Location:
Staten Island, N. Y.

Officials Interviewed:
Mr. E. Godoy, General Manager.
Mr. Hunter, Ship Constructor.
Mr. Scott, Chief Engineer.

General Remarks:
A small shipbuilding firm until 1916, when taken over by Cuban Financial House.

Methods of Construction:
Fabrication on site. Engines built for standard ships. (Triple expansion.) Scotch boilers.

Workers:
4,500 men.

Capacity:
Six slips.

Output:
Twelve 7,500 standard ships each 4½ months in slips, 1½ months fitting out. (First six are 14 months overdue on account of fire which destroyed Mould Loft and Plate Shop).

Oxy-acetylene Welding:

Oxy-acetylene used extensively for plate cutting, but little used for welding.

Arc Welding:

Has not been employed except in Machine Shops for special work.

Spot Welding:

Machine being installed to make steel templates.
Trial is being made of tools to heat rivets electrically.

Remarks:

By Mr. Scott:—Air Compressor Plant.

150 cub. feet of air (displacement) per minute per gang of riveters including

Drilling	65 cu. ft. per min.
Reaming	60 cu. ft. per min.
Riveting	35 cu. ft. per min.
Chipping, Caulking	30 cu. ft. per min.
Holder on, Rivet Fire	6 cu. ft. per min.

Required Capacity of Compressor:

50 per cent of total (usually 130 cubic feet, delivered) per minute per gang.

Cost of shipbuilding $180.00 per ton Deadweight.

FEDERAL SHIPBUILDING COMPANY
FEDERAL SHIPBUILDING COMPANY (F)

Visited:

7-3-18. Accompanied by Mr. Abrams of the Emergency Fleet Corporation, and Mr. Hobart.

Location:

Hackensack, N. J.

Officials Interviewed:

Mr. R. McGregor, General Manager.
Mr. McAlpine, General Superintendent.
Mr. L. B. Broadford, Chief Engineer.

General Remarks:

Yard laid out August 1914.

Contract placed for 9,600-ton standard ships.

Store Yard—Plates on edge. Riveting, one gang averaged 700 rivets per day.

Methods of Ship Construction:
60 per cent fabricated.
40 per cent erected on site.
Fabricated parts Midship Sections.
Inner Bottom Connections.
Outboard Intercostals.

Workers:
5,000 men.

Capacity:
10 slips (6 completed).

Output:
25 9,600-ton ships a year.
(One every two weeks).
Each 2 months on slips.
1 month fitting out.

Electric Welding:
Mr. McGregor favors adoption of spot welding employed on ship constructed of longitudinal channels 24" wide.
5 Electric Arc Equipments (Quasi) on order.

QUASI-ARC WELTRODE CORPORATION (G)

Visited:
7-3-18.

Officials Interviewed:
Mr. Alexander, President.
Mr. Moffat, Director.
Mr. Rigby, Australian Representative.

Supply Facilities:
Estimated output, 100,000 Weltrodes a week.
5 machines covering wire with yarn.
5 machines are on order (additional).
Electric Supply:
1 Welding Equipment on D. C. with Resistance.
2 Welding Equipments on A. C. (2 phase) with reactance in circuit.
1 Welding Equipment with transformer and resistance.

Training of Operators:

The firm have offered to instruct four welders in the use of Quasi System. Arrangements have been made by Mr. MacNary for this being done immediately.

BETHLEHEM STEEL CORPORATION (H)

(Moore Plant)

Visited:

8-3-18. Accompanied by Mr. Hobart.

Location:

Eizabethport, N. J.

Officials Interviewed:

Mr. George Wodey, Asst. Gen. Mgr.
Mr. A. L. Bursh, Shipyard Manager.

General Remarks:

Formerly S. L. Moore & Son. Old yard discarded 15 years ago, rebuilt in 1916.

Methods of Ship Construction:

Fabricated on site.
Plates developed on floor and fixed in position.
Templates for only 11 plates each ship. 96 per cent of vessel erected in position without fitting.

Workers:

1,360 men.

Capacity:

5 slips.

Output:

Contracts—2-3,800 cargo ships.
1-5000-ton tanker.
20 Tugs (27'6" x 6' x 15U'.)
First ship to be launched 4-17-18. It was started Oct. 25, 1917.

Electric Welding:

Has not been used but firm is anxious to favorably

consider the application. Mr. Bursh suggests welding the hull of a tug costing $300,000 comprising 275 to 300 tons of steel.

DOWNEY SHIPBUILDING CORPORATION (I).

Visited:
8-3-18. Accompanied by Mr. Hobart.

Location:
Staten Island, N. Y.

Officials Interviewed:
Mr. R. S. Armstrong, Assistant to Vice President.

General Remarks:
Formerly Mulligan Steel Works—Structural steel manufacturers.
Engines obtained from outside firms.

Methods of Ship Construction:
Fabricated parts received from own mills.

Workers:
1,000 men.
2,000 men shortly.

Capacity:
4 slips for 7,500-ton vessels.
3 more slips available when another contract is obtained.

Output:
Contract for 7,500-ton vessels to be delivered January, 1918. First of these vessels expected to be launched in May, 1918, and one a month thereafter.
Notes by Mr. Armstrong:
2,500 tons of steel per ship.
500,000 rivets per ship.
200 rivets to the ton.

Electric Welding:
It was stated that no electric welding was being done except the repair of shell plates, etc., by means of a hired plant, but on going through the shops it was ascertained that a welding plant had been installed by the Quasi-Arc, connected to 220 Volts, D. C. and was used extensively in the machine and engine repair shop by Fred Tye, who is a most efficient operator with both bare metal and flux-covered electrodes.

Report Number Three

BROOKLYN NAVY YARD—U. S. NAVY DEPARTMENT (J)

Visited:
9-3-18.

Location:
Brooklyn, N. Y.

Officials Interviewed:
Admiral Burd, Industrial Manager.
Captain Rock, Naval Constructor.
Commander Dungan, Engineer Officer.
Lieutenant Commander Winston, Asst. Engr. Officer.
Lieutenant Carmichael, Asst. Naval Constructor.
Lieutenant Fulton, Asst. Naval Constructor.
Lieutenant B. F. Hart, Engineer Officer.
(Supervised repairs to German ships.)
Lieutenant Kraemer, Engr. Officer.
(Supervised repairs to German ships.)

General Remarks:
The usual output of the Machinery Division has increased four times in quantity during the last year, while less men were employed in proportion thereto.

Methods of Ship Construction:

Workers:
5,000 enlisted men.
17,000 civilians.

Electric Welding:
Hull Construction Division has Quasi-Arc Equipment, 250 volts, D. C. 1 Bare Metal Equipment.

Electric welding is limited here to the repair of steel castings and stern posts on Destroyers.

Machinery Division has four Wilson portable equipments, and one Quasi-Arc Equipment, 220 volts, D. C.—2 additional ones on order. The Wilson plant was used for steel work on boilers and cylinders, while the Quasi-Arc equipment was chiefly used for reinforcing defective steel castings. The interned German vessels were shown to me, and along with Lieutenant Kraemer I inspected the Princess Irene. The Chief Engineer of the Princess Irene explained that no trouble had been experienced, with the exception of a leak at the welded structure of the H. P. cylinder through the space between the top of the liner and the cylinder cover. During the first voyage the valve casing was shattered, due to a large nut having been left inside. This was repaired in France, where shattered

parts were reached, and steel studs placed inside the opening prior to the addition of the welding material. Examples of work:

Lubricating oil tanks in Submarine Chasers 24"x4'x ¼" H. P. Tanks to contain exhaust steam to operate M. B. Whistle 18" pipe with blanks welded to ends tested to 300 lbs.

FORE RIVER SHIPBUILDING COMPANY (K)

Visited:
16-3-18. Accompanied by Mr. Stevens and H. M. Hobart.

Location:
Quincy, near Boston.

Officials Interviewed:
Mr. E. H. Ewertz, General Superintendent.
Mr. J. F. Clinton, Electric Engineer.
Mr. W. L. Roberts, Welding Expert.
Mr. Williams, Supt. Constructor.

General Remarks:
This shipyard has been in operation for the last 20 years, and has been considerably extended during the past year. Mr. Ewertz is a great authority on Submarine Construction, having assisted Mr. Holland with his first submarine. New works have been erected, to manufacture steam turbines, at Buffalo, and an additional shipyard is being laid out at Squantum, the latter plant to be used for the purpose of completing the contract for 35 torpedo boats.

Capacity:

At Quincy: 46 slips.	1 for Battle Cruiser.
	6 for Merchant Vessels.
	8 for Torpedo Boats.
At Squantum:	32 for Submarines.
	Also 2 fitting out docks.
	35 Destroyers.

Output:
Torpedo Boats, 140 days in slips, 120 days in fitting out docks. Submarines, 3 months in slips, 2 months in fitting out docks. Other firms build submarines complete

for service, on slips. All pipe connections, etc., are fitted on complete wood model of the hull to template. Inspected two such models with fittings in position.

Electric Welding:

Electric Welding used extensively to weld staples, etc. Submarine tank ends were welded and tested to 180 lbs. pressure. A pin hole leak was made satisfactory by caulking, though end of tank bulged out.

Design for Torpedo Boat prepared by Mr. Ewertz for electric welding.

Electric Welded Torpedo Boat:

Mr. Robert's estimate of No. of running feet for welding.

(1) Shell with lapped seams and butts	
7 fore and aft	
ship 310 ft. long	
7 x 310 (P. & S.)	4,340 ft.
(2) Shell Butts, say	700 ft.
(3) Main Deck.	
4 seams fore and aft	
4 x 310	1,240 ft.
(4) M. D. Butt 70 x aver. of 5 ft.	350 ft.
(5) Platforms	
Estimated Butts and Seams	1,500 ft.
(6) Bulkheads (Transverse)	2,400 ft.
(Fore and aft)	600 ft.
	12,000 ft.

Comparison (date of laying keel to date of launching)

Riveting: 30 gangs approx.	100 men	104 days
Electric Welding:	12 men	50 days
	Saving	54 days

Unit comparative cost of main deck construction.

Present method	$18.44
Electric Welded method	10.13

In addition the moulding loft template of plate for welding would be approx. ½ for riveted construction.

Suggested details of Electric Welded Construction—(Developed by Mr. Ewertz)

(1) Connections of transverse bulkheads and Platform Deck with shell showing bounding angles and jogging.

(2) Connection of transverse bulkhead with vertical keel showing staples and small parts.

(3) Connection of centre line bulkhead and transverse bulkhead with second deck showing bounding angles

and joggling.
(4) Deck plan showing butt of 6 lb. and 10 lb. plate and seams of 6 and 10 lb. plate with 20 lb. stringer plate.
(5) Longitudinal W. T. Bulkhead 24 inches from centre line of ship on port side (staples eliminated).

RIVER WORKS (GENERAL ELECTRIC CO.) (L)

Visited:
3-19-18. Accompanied by Mr. H. M. Hobart.

Location:
Lynn, near Boston.

Officials Interviewed:
Mr. L. E. Underwood.

General Remarks:
The mass production of motors was most interesting. For sizes up to 25 H. P. the output of motors for 1917 was 132,000.

In Power House a 4,500 H. P. Turbine is supported on 4 steel standards, H beams 12"x12" with horizontal members 12"x4"x$\frac{9}{16}$". Turbine has no bedplate. Laid direct on this steel frame support.

Electric Welding:
Arc System in use with bare metal electrodes.

THOMSON WELDING COMPANY (M)
LABORATORY AND WORKS

Visited:
3-19-18. Accompanied by Mr. H. M. Hobart.

Location:
Lynn, near Boston.

Officials Interviewed:
Prof. Elihu Thomson.
Mr. Cutter.
Mr. Walcott Remington.

General Remarks:

The inspection of these Works was principally of interest as being where the earliest forms of resistance welding machines were manufactured. Viewed several spot and butt machines in operation and process of erection. Bull Riveter converted to spot welding for plates from ½" to ⅝" thick. Total weight 4 tons. Cast Copper used for transformers has a conductivity nearly equal to that of drawn wire. Discussed method of welding end of cylinders for Liberty Motor with Prof. Thomson.

WM. CRAMP & SONS SHIP & ENGINE BUILDING COMPANY (N)

Visited:

3-21-18. Accompanied by Messrs. Adams, Stevens and Hobart.

Location:

Philadelphia.

Officials Interviewed:

Mr. J. H. Mull, President.
Mr. Knockersperger, General Manager.
Mr. Cramp, Jr.

Methods of Construction:

Fabrication on site. This firm has been in business for 50 years. It introduced pneumatic riveting into Britain and at the request of Lord Pirrie and Prof. Biles, sent plant and men to Harland & Wolff's Yard.
Torpedo Boats and Troop Ships.
80 per cent Navy work.
Torpedo Destroyers.
4 to 5 months in slips.
2 months fitting out.
One vessel every two weeks.

Work on Hand:

9 commandeered ships being refitted.
46 Torpedo Destroyers.

Ways:

13 slips.

Electric Welding:

Arc System with Carbon and Bare Metal Electrodes.

Equipments.

2,400 amp. 74 volt machines—one operator.
1,600 amp. 70 volt machines—two operators.

The bulk of electric welding has been done by the carbon arc and is used to replace blacksmith welding the following:

Boiler plate shapes	Ventilating Pipe Coamings
Bulkhead frames	Davits
Staple bars	Stowage Racks
Angle rings	Fixing Clips (Hatchways)
Deck frames	

Simplified designs of above structures, with piece work rates, have been prepared and issued to workers.

Simplified designs of above structures have been prepared and issued to workers.

Galvanized work is welded with the carbon arc after grinding away as much of the galvanizing as possible. Mr. Mull stated that only 5 per cent of the work is carried out with the metal electrode. Mention was made of attempts to weld a boiler with the carbon arc so it is understood the firm now understands the limitations of this system.

Complaint was made of the conservative action of Lloyds, the following instances being cited:

(1) 4 Steel Stems were condemned by Navy Department within a month, which could have been satisfactorily repaired by electric welding.

(2) Holes were out of line in length of angle bar framing. Lloyds would not sanction the filling up of one set of holes by electric welding but suggested and passed the countersinking of angle frame holes and putting in plug rivets.

It is apparent that this firm does not realize the extent of electric welded work now approved by the Navy Dept. For instance: It was noted that staples for Destroyers were being blacksmith welded although Mr. Mull said he would prefer to do this work electrically.

Hull Construction:

Mr. Mull has very strong views against the employment of electric welding to join hull plates of a ship. He believes it would cost as much to prepare a ship for welding as for riveting. It was his opinion that whereas plating was the most complicated operation the riveting presented no difficulties either as regards obtaining sufficient skilled riveters or the cost of this work. In support of this statement the following costs of driving rivets on the previous day were mentioned:

Pneumatic:

7	Gangs	434 rivets a day
2	Gangs	442 rivets a day
3	Gangs	444 rivets a day
10	Gangs	446 rivets a day
51	Gangs	450 rivets a day
17	Gangs	805 rivets a day

Hand:

5	Gangs	434 rivets a day
1	Gang	442 rivets a day
2	Gangs	444 rivets a day
1	Gang	446 rivets a day
1	Gang	450 rivets a day
100		42,655

Total wages paid for 42,655 rivets $1,312.66
Average cost per rivet 3.1c
Add 21 per cent bonus 3.75c

The above figures refer to 5/8" rivets, every hole being reamered and prepared to encourage a big drive.

CHESTER SHIPBUILDING COMPANY (O)

Visited:
3-22-18. Accompanied by Mr. Stevens.

Officials Interviewed:
Wm. T. Bonner, Engr. Welded Ship Construction.
L. T. Kniskern, Asst. General Manager.
J. G. Dudley, Office Research and Experimental Dept.
W. J. Jones, Office Research and Experimental Dept.

Location:
Shipyard at Chester near Philadelphia.
Executive offices: Finance Bldg., Philadelphia.

Methods of Construction:
Stock Ships 85 per cent fabricated by American Bridge Co.
Mine sweepers. All parts fabricated on site.

Output:

	Present.	Future
On slips	5 months	4 months
Fitting out	5 months	5 weeks

Steam Turbines obtained from Westinghouse Company.
Cargo Ships 8,800 tons, standard type.
Tank Ships 10,500 tons.
Mine sweepers 4 on order from Navy Dept.

Workers:
2,200 men employed now.
7,000 men shortly.

Electric Welding:
Arc system in extensive use with bare metal electrode.
Equipments.
(A)—5 stationary machines to serve—5 operators.
(B)—1 stationary machine at 60 volts—6 operators.
(C)—1 portable machine at 60 volts—1 operator.
including carbon pile substitutional resistance.
(A)—3 Siemund-Wenzel E. W. Co. Single Arc Sets Oil Transformer Type Reactance.
(A)—2 Arc Welding M. Co. Single Arc Sets Carbon Pile Resistance.
(B)—1 Arc Welding M. Co. Six Arc Sets Carbon Pile Resistance.
(C)—1 General Electric Co. Single Arc Portable Set —C. I. Grid Resistance.

Hull Construction:
It was stated that a 60 ft. section of plating of an oil barge built at Newburgh was assembled under the direction of Mr. Bonner, and that many tests of various types of plating jointures had been made to determine their relative value for ship construction.

I inspected a full size section of the bilge portion of a 10,500-ton cargo ship which has been completely welded by Mr. Bonner. No figures were submitted as to cost of electric welding this job, but I would expect very considerable saving would be effected by simplifying the design of parts to be joined, thereby reducing the number of welds necessary and also reducing the section of added metal. Moreover, such amendments would reduce the internal stress and increase the strength of the whole structure.

NEW YORK CENTRAL RAILROAD
WEST ALBANY SHOPS (P)

Visited:
3-25-18. Accompanied by Messrs. Hobart, Gilson, Weed and Muir.

Location:
Albany, N. Y.

Officials Interviewed:
Mr. C. J. Holslag, Elect. Eng.
General Manager and others.
Workers:
1,117 men.

Output:
Construction and Repair of Locomotives.

Electric Welding:
Arc system with bare and flux-covered metal electrodes.
Equipment:
6 Wilson machines (D. C.)
1 Holslag Machine (A. C.)
Comparative cost of electrode wire.
Electrodes supplied by Quasi-Company 28c a lb.
Bare rod supplied by Wilson Company 15c a lb.
Bare rod supplied by Quasi-Company 28c a lb.
Cast iron repairs have been successfully executed at this shop, but always with steel studs and reinforcing of parts prior to welding. Muir was very satisfied with the Arc obtained through the Holslag Machine with Quasi and bare metal electrodes.

NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY (Q)

Visited:
3-27-18. Accompanied by Messrs. Adams, Stevens and Hobart.

Location:
Newport News, Va.

Officials Interviewed:
Mr. J. F. Nichols, Chief Engineer.
Mr. H. I. Walsh, Welding Foreman.
Mr. E. I. Cornbrooks, Supt. Hull Construction.

General Remarks:
Electric arc welding with bare metal electrodes has been extensively adopted at this yard and much good work has been done.

Labor:
Normal, 12,000 men.
Now, 8,000 men.
50 per cent is colored labor.

Output:

7 slips 500 ft. long.
3 drydocks.
Additional (2 slips 850 ft. long)
(2 slips 1000 ft. long)
Work in process for Navy Department.
2 Battleships
2 Battle Cruisers
31 Torpedo Destroyers
Oil and cargo vessels constructed up to 15,000 tons.

Electric Welding:

2 General Electric 15 K. W. 200 Amp. Arc Welders.
3 General Electric 18 K. W. 300 Amp. Arc Welders.
1 C. & C. Type S. L. 600 Amp. Arc Welders.
1 man on each 200 Amp. Machine.
2 men on each 300 Amp. Machine.
3 men on each 600 Amp. Machine.
1 G. E. 75/75 volt 1250 Amp. Arc Welding Set on order, will work 6 welders on same.
66 Davis Bournonville Cutting Torches No. 3000.
2 Oxweld Shipyard Cutting Torches.
2 Radiographs complete.
7 D. B. Circular cutting hand torches.
2 Mechanical Oxygen Hydrogen torches.
1 Hand Oxygen Hydrogen torch.
12 D. B. Style "C" Welding torches.
4 D. B. Small Style "C" torches.
2 D. B. Long Style "C" torches.
1 D. B. Midget Welding Torch.
10 Vulcan Welding Torches.
2 Vulcan Welding Long Torches.
112 225-cu. ft. Acetylene Tanks.
2 300-lb. Acetylene Generators.
1 200-lb. Acetylene Generator.
11 Electrolytic Cells for making oxygen and hydrogen.

Operators:

Gas and electric welders.
Total 125 including 11 experienced gas welders.
9 experienced electric welders.
Examples of electric welded work inspected:—
Flanges joined to pipe stanchions.
Drain pockets.
In branch pipes, holes filled up.

Seventeen German liners were repaired at their yard. Mr. Walsh said the attempts at electric welding of cast iron parts were unsuccessful except when studs were inserted in C. I. parts to be laced to new steel parts. Acetylene welding with cast iron filling rod was success-

fully employed for these C. I. repairs with flux comprising carbonate of soda and ferrosilicate.
Corroded Train Ferry Bottom Plating built up.
Gridiron on stern post; broken part reinforced with new metal.
Steam and air pipe lines in Yard and Power House electric welded complete.
Outboard Thrust Bearing of Torpedo Boat; steel casting reinforced.
Engine main shaft—reinforced at one bearing surface.
Electric welding wire obtained from Messrs. J. A. Roeblings & Sons Company, Trenton, N. J.

Oxy-Acetylene Producing Plant:
Oxygen-Electrolytic process 11 cells capacity.
45 cu. ft. per cell per hr. i. e. 1,200 cu. ft. per 24 hrs.
Compressors—

Oxygen	1,800 pounds
Hydrogen	600 pounds
Acetylene	300 pounds

NORFOLK NAVY YARD (R)

Visited:
3-28-18. Accompanied by Messrs. Adams, Stevens and Hobart.

Location:
Portsmouth, Va.

Officials Interviewed:
Naval Constructor Watt, U. S. Navy.
Naval Constructor Knox, U. S. Navy.

Workers:
8,500 men.

General Remarks:
In addition to ordinary repair work usual at Navy Yards, a certain amount of building work is executed. At present, there are 3 drydocks in service. Turbines for Torpedo Boats, etc., are being assembled from parts partially obtained from outside firms. Large quantities of accessories such as seamen's mess tins, lockers, etc., also powder containers, paint drums and other sheet metal work is made at the Portsmouth Yard.

Electric Welding:

Both spot and arc system of electric welding are in use.

Plant Spot Welding Machines:

1. By Thomson Electric Welding Co.
   (Lachman Patent)
2. By National Electric Welder Co.

Arc Welding Machines:

1 Quasi Arc.
1 C. & C. Machine with 4 panels.
2 Wilson Machines with 4 panels.
2 Wilson Machines with 2 panels (on order).
4 Wilson Machines with 16 panels (on order).
2 Welding Operators preferred C. & C. machines.

Witnessed the welding of pipe (long seam) by same operator with Wilson & C. & C. equipment. Results appeared equal. With "Roebling" wire electrode best results seemed to be obtained with Wilson machine.

Operator Screens:

Glass (Noviweld No. 12) purchased from F. A. Hardy & Co., N. Y., made by Corning Glass Co., Corning, N. Y.

Trimming of scrap from "Armco" American Rolling Mills Co.'s product used successfully as electrode when polarity reversed.

Automatic Machine.

Viewed Automatic machine for electric welding the circular seam of Mines. This machine has the following features.

(1) Length of electrode regulated by small motor, field strength varied by length of arc.

(2) Mine rotated by small motor—when arc breaks electrode rests on surface of mine and is raised to strike arc when starting again by solenoid.

(3) Arc directed vertically on work by "blow out coil around top of arc." Arc keeps vertical, which is the easiest path due to lines of force set up by magnetic coil.

(4) Side motion given to electrode if desired, by hand.

Naval Constructor Knox said that with the Automatic Welding Machines the circ. seam of mines would be welded in 15 minutes instead of 60 minutes as taken by his operators now. Spot welding is used to join galvanized powder containers and fix high carbon steel tips to tool shanks.

Oxy-acetylene Producing Plant:

Oxygen produced by Electrolytic Process—50 Davis Bournonville cells.

Accumulators for Oxygen and Hydrogen compressed to 150 lbs. for use in shops—supply through pipe main around shops—Pressure Acetylene Generator, 15 lbs. for supply to shops in pipe main. Cylinders for isolated use.

(1) Oxygen and Hydrogen 1,800 lbs.
(2) Acetylene 225 lbs.

Arrangement of Compressors.

(1) Oxygen 300 pounds
(2) Hydrogen
(3) Oxygen 1,800 pounds
(4) Hydrogen
(5) Acetylene 225 pounds

NEW YORK SHIPBUILDING CORPORATION (S)

Visited:

4-3-18. Accompanied by Mr. H. M. Hobart.

Location:

Near Philadelphia.

Officials Interviewed:

M. A. Neeland, President.
H. A. Magoun, Vice-President.
N. deTaube, Vice-President.
W. G. Groesbeck, Asst. to President.
A. Parker, Electrical Engr.

General Remarks:

This yard has been in existence about 19 years, primarily for ship building by the template system. The equipment is excellent, the slipways are entirely covered in and fitted with overhead travelers. The Battleship "Idaho" which was built here is now being fitted out. (Displacement 32,000 tons, 624 ft. x 100 ft. Twelve 14" guns—Launched June, 1917.)

Workers:

9,500 men.

Method of Ship Construction:

Fabrication on site. Complete bulkheads assembled in yards are lifted into position by overhead cranes.

Building Slips:
3 slips— 600′ long
1 slip — 690′ "
1 slip — 800′ "
2 slips—1000′ " Those over 600 feet not yet completed.

Output:
1917—100,000 tons
1918—120,000 tons (estimated)

Electric Welding:
Spot welding is now employed in the manufacture of ventilating trunks, etc. A trial has been made to spot weld watertight doors with arc welding at edge seam, (spot welded bars failed at 20 pounds pressure).

Arc Welding:
With bare metal electrode used mainly for repair of defective castings. Equipment 1 Machine 50KW (DC). Arrangements were made to send Muir to give demonstration with flux-covered metal arc system.

HOG ISLAND SHIPYARD
of the
AMERICAN INTERNATIONAL SHIPBUILDING CORPORATION (T)

Visited:
4-4-18. Accompanied by H. M. Hobart.

Location:
Near Philadelphia.

Officials Interviewed:
Mr. J. H. Manning, Assistant to
Mr. G. O. Muhlfeld, Vice Pres.
Mr. J. H. Anderton, Electrical Engineer
P. B. Streander, Asst. Progress Depart.
T. E. Valtfort, Progress Engineer
A. L. Snyder, Executive Department

General Remarks:
This is a wonderful example of efficient organization. The layout was started six (6) months ago. Already eight (8) keels have been laid and speedy construction will result on delivery of fabricated steel parts. A full description is attached. The system of charts showing

the various stages of completion of work was most interesting.

Labor:
15,000 men now
32,000 men later.

Method of Ship Construction:
Fabricated parts will be delivered from 47 steel mills. Shops have been erected for the carrying out of necessary alterations.

Output:
50 ships (1918)
Contracts placed for
(a) 110-7,500-ton standard vessels.
Speed, 11 knots; power, 2500 HP
(b) 70-8,000-ton standard vessels
Speed, 15 knots; power 6000 HP

Electric Welding:
Spot welding. 2 portable and 2 stationary machines have been ordered to join heavy ship-plates.

Arc Welding:
Several equipments by different makers have been ordered. It is intended to organize a school for electric welding operators at this yard. Mr. MacNary will arrange for the instruction of men required by this and other concerns engaged on work for the Emergency Fleet Corporation. In the first instance, it is proposed to weld fabricated parts, fittings and non-structural work.

THE NATIONAL MALLEABLE CASTINGS CO. (U)

Report of Visits to Works at Sharon and Cleveland

Visited:
9-4-18. Accompanied by Prof. Adams.

Officials Interviewed:
Mr. L. L. Smith } Vice Presidents
Mr. W. G. Kranz }
Mr. C. W. Hotchkiss, Manager Cleveland Plant
Mr. C. K. Brooks, Manager Research Department
Mr. R. W. Ewing, Engineer
Mr. J. H. Redhead, Manager Sales Department
Mr. J. B. Kitteredge, Manager Sharon Plant
Mr. W. B. Caldwell, Engineer

Report Number Three

FORD MOTOR COMPANY (V)

Visited:

4-10-18. Accompanied by Messrs. Adams, Stevens and Rigby.

Location:

Woodward Avenue, Highland Park, Detroit, Mich.

Labor:

30,000 men

Three shifts (1) 20,000
(2) 6,000
(3) 4,000

Officials Interviewed:

Mr. W. S. Knudson, Superintendent Construction
Mr. W. S. Mayo, Chief Engineer
Mr. F. Allison, Electrical Engineer

General Remarks:

In addition to manufacturing motor cars, ambulances and army service vans, the firm is engaged on various munition parts. The development of the submarine chaser is interesting, as it is expected to turn these out at the rate of one per day. A new factory is being erected for the assembly of these boats from parts made to gauge and template on model vessel at the car shops. A description of the new shipbuilding shops is attached.

Method of Ship Construction:

The entire design and construction of the submarine chasers is revolutionary. There is an absence of "lines" so that flat plates are largely employed. In fact there are only four (4) patterns of bent plates and these are pressed cold to the correct shape in machines. Frames, etc., all of special design, are made up of channel pieces formed to shapes from plate pieces.

Output—Automobiles:

Normal, 3,000 a day
At present, 1,500 a day

Submarine Chasers:

Estimated 1 boat a day.

Electric Welding:

Spot welding has been tried in car factory with unsatisfactory results. Arc welding has not been employed until recently when two "Wilson" and one "General Electric" machines were purchased. I offered Muir's services to demonstrate bare metal and flux-covered electrode arc welding. It was decided to obtain one Quasi Arc equipment.

Report No. 4

THE ELECTRIC WELDING COMMITTEE OF THE EMERGENCY FLEET CORPORATION

A—List of members.
Minutes of first meeting
B—Minutes of second meeting
C—Minutes of third meeting
D—Recommendations by Naval Constructor Knox
E—Proposed electric welded construction of 5,000-ton standard ship by Messrs. Ewertz and Knox
F—Captain Caldwell's Report to Welding Committee on:
(1) Propaganda in Britain
(2) Training of welding operators
(3) Preparation of work for welding
G—Circular letter sent to shipyards
H—Circular letter sent to manufacturers of welding apparatus.

SECTION A

MEMBERS OF WELDING COMMITTEE (3-21-18.)

C. A. Adams, Chairman, 33 West 39th Street, New York City, Room 716.

A. J. Mason, 1319 F Street, N. W., Washington, D. C.

E. E. MacNary, 136 South 16th Street, Philadelphia, Pa.

E. A. Stevens, Jr., 33 West 39th Street, New York City, Room 716.

D. B. Rushmore, General Electric Company, Schenectady, N. Y.

H. M. Hobart, General Electric Company, Schenectady, N. Y.

W. L. Merrill, General Electric Company, Schenectady, N. Y.

Captain James Caldwell, R. E., British War Mission, 681 Fifth Avenue, New York City.

Maurice Lachman, 30 East 42d Street, New York City.

Elihu Thomson, General Electric Company, West Lynn, Mass.

Eric Ewertz, Bethlehem S. B. Corporation, Quincy, Mass.

J. G. Dudley, Chester S. B. Corporation, Finance Building, Philadelphia, Pa.

W. T. Bonner, Chester S. B. Corporation, Finance Building, Philadelphia, Pa.

H. A. Hornor, Hamilton Court, Philadelphia.

Clark Henderson, Submarine Boat Corporation, Newark, N. J.

Captain O. W. Koester, U. S. N., Bureau Steam Engineering, Washington, D. C.

Naval Constructor S. M. Henry, U. S. N., Bureau Construction and Repair, Washington, D. C.

Naval Constructor H. G. Knox, U. S. N., Navy Yard, Norfolk, Va.

Report Number Four

MINUTES OF FIRST MEETING OF ELECTRIC WELDING COMMITTEE

The first official meeting of the Electric Welding Committee of the Emergency Fleet Corporation was held at the headquarters of the American Institute of Electrical Engineers, New York, on Saturday, March 23d, 1918, at 9.30 A. M.

Chairman C. A. Adams called the meeting to order at 9.45 A. M.

Present:

Professor C. A. Adams, Chairman.
Captain James Caldwell (Admiralty, London).
Messrs. E. H. Ewertz (Bethlehem Shipbuilding Corp.)
C. T. Henderson (Submarine Boat Corp.).
Edmund J. Henke (Thomson Electric Welding Co.).
Henry M. Hobart (General Electric Company).
H. A. Hornor, Philadelphia, Pa.
Walter J. Jones (Chester Shipbuilding Co.).
H. G. Knox (U. S. Navy).
O. W. Koester (U. S. Navy).
M. Lachman (Universal Electric Welding Co.).
E. E. MacNary (Emergency Fleet Corp.).
Arthur J. Mason (Emergency Fleet Corp.).
W. L. Merrill (General Electric Co.).
Henry C. E. Meyer (American Bureau of Shipping).
Wolcott Remington (Thomson Electric Welding Co.).
David B. Rushmore (General Electric Co.).
Geo. G. Sharp (American Bureau of Shipping).
E. A. Stevens, Jr. (Emergency Fleet Corporation).
H. J. Cox (Lloyds Register of Shipping).

Chairman Adams addressed the meeting explaining how the present question of electric welding has been taken up by the Standards Committee of the A. I. E. E. as a good and economical means of replacing riveting in certain parts of shipbuilding. Also that when Mr. Hobart was sent over to London to a conference with the Standards Committee, he was requested as a member of the Committee on Electric Welding to see what was being done on the other side in the electric welding field and to tell them what we were doing. As a result of that mission, Mr. Hobart got in contact with

the British Admiralty, and Captain Caldwell was allowed to come over here on behalf of the Fleet Corporation to tell us what they had been doing and to co-operate with us in any possible way in the advancement of this application.

The chairman further stated that on the 21st of February, 1918, after a number of conferences with the Fleet Corporation representatives, a small committee was appointed by the Fleet Corporation as follows: C. A. Adams, chairman, Mr. E. A. Stevens, Jr., and Mr. A. J. Mason, both of the Emergency Fleet Corporation, and Mr. D. B. Rushmore as a nucleus, with the request that that committee expand in such a way as to take in all of the interests involved.

Chairman Adams read a letter from Mr. D. H. Cox, Manager of steel ship construction of the Emergency Fleet Corporation, stating that the Emergency Fleet Corporation was depending upon this committee to use all possible efforts in forwarding the work.

Chairman Adams asked Captain Caldwell to address the meeting and briefly outline the work which the British Admiralty has done in the field of electric welding.

Captain Caldwell stated that since the war broke out the demand for gas for oxyacetylene welding was so great that electric arc welding was taken up as a substitute, with the result that it was found in most cases superior to the oxyacetylene welding. He cited many applications of electric welding such as mines, bombs and other munitions, steel tires, wheels, etc., auxiliary bulges (or blisters) on battleships and cruisers for protection against torpedoes; frames, floorplating, etc., of small vessels, and in one case, of a barge completely welded. Captain Caldwell had much valuable data which he gathered on his trips to various shipbuilding yards both here and in England, which will be submitted to the members of the committee.

Chairman Adams called attention to the fact that the Committee on Electric Welding had opened an office in the Engineering Societies Building, Room 716, where all information regarding activities in electric welding could be found.

Chairman asked Mr. Mason, of Emergency Fleet Corporation, to address the meeting.

Mr. Mason explained how much time would be saved by electric welding on ships and this system of riveting and thereupon drew on the blackboard a midship section, explaining the time saved over that required for assembling the parts together by riveting. Mr. Mason thought that with material on hand and the system of electric welding used, it ought to be possible to assemble the frame of a ship in three weeks.

The chairman asked Constructor Knox to address the meeting, who outlined his ideas of the work which the committee should take up.

Captain Koester was then asked by Chairman Adams to give a brief outline of the work done by him in the Navy Department. He stated that on the German ships taken over by the Navy he found breakages on all cast iron parts. Many of these breaks, he stated, have been repaired by electric welding and the ships have made three or four voyages, without complaint.

Mr. Merrill, upon request by Chairman Adams, outlined the experiments carried on by the General Electric Company on the successful spot-welding of plates up to 1". This was followed by discussion between the members.

Mr. Rushmore stated that the object of the committee is to build more ships in the shortest time by the proper use of electric welding. He said arc welding and spot welding can be done satisfactorily, but that no one should be allowed to weld American ships who is not a good welder and working under an inspector who is properly certified and approved. Mr. Rushmore thought that the subject of immediate and careful thought should be the program to be followed by the committee—what is needed in the way of equipment, manufacturing facilities, etc.

This led to the question of a Program Committee, and Chairman Adams selected the following members to form this committee to present to the Electric Welding Committee a program at the earliest possible moment: Messrs. Rushmore (chairman), Knox, Stevens, Ewertz, Sharp, Caldwell, Hobart, Lachman, Hornor, Cox, of Lloyds, and C. A. Adams, ex-officio.

The above Program Committee was authorized to send out a report to all members of the committee, which is to be returned with comments.

Mr. Rushmore offered the suggestion that only men in the uniform of the Army or Navy be permitted to be welders.

Captain Koester suggested that a committee be sent around to the various shipyards doing government work now, to go over the situation and see what can be done to speed up welding. Whereupon Chairman Adams appointed Mr. Stevens, chairman, Captain Caldwell and Mr. Hobart, to report on the conditions found in the shipyards visited, at the next meeting.

Meeting adjourned at 1.35.

Respectfully submitted,

C. A. ADAMS, Chairman.

SECTION B

MINUTES OF SECOND MEETING OF ELECTRIC WELDING COMMITTEE

The second meeting of the Electric Welding Committee of the Emergency Fleet Corporation was held at the headquarters of the American Institute of Electrical Engineers, New York, on Saturday, March 30th, at 9.30 A. M.

Chairman C. A. Adams called the meeting to order at 9.45 A. M.

Present:

E. E. MacNary
E. A. Stevens, Jr.
D. B. Rushmore
M. Lachman
W. Remington
W. J. Jones
W. T. Bonner
H. A. Hornor
C. Henderson
Captain Jessups, U. S. N.
S. M. Henry, U. S. N.
H. G. Knox, U. S. N.
H. C. Meyer
H. J. Cox
D. H. Wilson, Jr.
J. A. Osborn
D. C. Alexander
E. J. Rigby

Minutes of previous meeting were not ready for reading.

Chairman Adams passed around a copy of Captain Caldwell's document. (See Section F.)

Mr. Rushmore read a list, submitted by Mr. Stevens, of parts of a vessel which could be electrically welded, this list being approved by the Classification Societies. (See Report No. 13.)

Mr. Rushmore then read a letter from Mr. Knox containing the interesting program which he had prepared and involving also the sub-committees to which the various parts of the

program could be assigned. After much discussion this letter was revised somewhat and a copy of letter as it now stands, is given in Section D. Recommendations made by Messrs. Ewertz and Knox for the construction of standardized ships such as one of the ships now being built at the Submarine Boat Corporation are given in Section E.

The Chairman then called attention to resolutions passed at the different district meetings of the Emergency Fleet Corporation held at New York, Boston, Philadelphia and Baltimore recommending that a 5,000-ton electrically welded ship be built and that the Emergency Fleet Corporation be urged to order the shipyards now building ships to apply electric welding methods wherever it is possible to do so; it was also resolved to urge the training of electric welders.

The Chairman then read a list of electrical welding companies which have been called upon for assistance; these were as follows:

General Electric Company
C. & C. Electric Company
Lincoln Electric Company
Westinghouse Electric Company
Burke Electric Company
Wilson Welding & Metals Company
Quasi-Arc Weldtrode Company
Siemund-Wenzel Electric Welding Machine Co.

Chairman Adams then appointed sub-committees to serve as follows:

Executive Committee.

C. A. Adams, Chairman
E. A. Stevens, Jr.
H. G. Knox
D. B. Rushmore

Approval of Tests Committee.

E. A. Stevens, Chairman
H. J. Cox
H. C. Meyer
H. G. Knox
S. M. Henry

Ship Design Committee.

E. Ewertz, Chairman
H. G. Knox
E. A. Stevens, Jr.

C. Henderson
H. Lachman
H. A. Hornor
D. H. Wilson, Jr.
W. T. Bonner
Classification Society representatives

Equipment and Power Supply Committee.

W. L. Merrill, Chairman
H. A. Hornor
D. H. Wilson, Jr.
D. C. Alexander, Jr.
O. A. Kenyon

Research Committee

H. M. Hobart, Chairman
J. H. Nelson
H. G. Knox
W. J. Jones

Training Committee.

E. E. MacNary

(Mr. MacNary was called upon to select his own committee.)

Committee to Visit Shipyards.

E. A. Stevens, Jr., Chairman
Captain J. Caldwell
H. M. Hobart

Program Committee.

D. B. Rushmore, Chairman
H. G. Knox
G. G. Sharpe
H. M. Hobart.
H. A. Hornor
C. A. Adams, ex-officio
E. A. Stevens, Jr.
E. Ewertz
J. Caldwell
M. Lachman
H. J. Cox

Mr. Henderson proposed the following resolution:

Resolved, that the committee urge the immediate authorization of the construction of a 5,000-ton electrically welded ship, this ship to be constructed for the purpose of demonstrating the practicability of such procedure and determining the economic possibilities of such construction.

After much discussion this was seconded and approved by all with the exception of Naval Instructor Henry.

Then Mr. Bonner proposed the following resolution:

Resolved, that this committee recommend to the Emergency Fleet Corporation the appointment of a Board of Design consisting of one representative each from Lloyds and the American Bureau of Shipping, two Shipping Board Engineers, two Naval Constructors, two Naval Architects, two structural steel engineers, and two experienced welding designers, in addition to our chairman, ex-officio, this board to proceed at once with the preparation of general and detail drawings for a 5,000-ton all welded cargo ship to be adopted as standard for use by all of the yards engaged in the construction of ships for the Emergency Fleet Corporation and U. S. Shipping Board.

Mr. Henderson made a motion that this be laid on the table until next meeting.

This motion was seconded and accepted by all.

Mr. Henderson made a motion that the meeting adjourn. This was seconded and accepted.

Meeting adjourned at 2.30 P. M.

Respectfully submitted,

C. A. ADAMS, Chairman.

SECTION C
MINUTES OF THIRD MEETING OF ELECTRIC WELDING COMMITTEE

The third meeting of the Electric Welding Committee of the Emergency Fleet Corporation was held at the headquarters of the American Institute of Electrical Engineers, New York, on Monday, April 8, 1918, at 9.30 A. M.

Chairman C. A. Adams called the meeting to order at 9.45 A. M.

Present:

Captain James Caldwell
Messrs. E. E. MacNary
E. A. Stevens, Jr.
D. B. Rushmore
H. M. Hobart
W. L. Merrill
W. Remington
E. Ewertz
W. J. Jones
W. T. Bonner
H. A. Hornor
C. Henderson
H. J. Cox
D. H. Wilson, Jr.
D. C. Alexander
E. J. Rigby
J. H. Anderton

By Invitation:

Charles Wirt
C. K. West

The minutes of the first two meetings were accepted as read.

The first matter brought up for attention by Chairman Adams was the selection of the committee to visit shipyards as he explained that due to Captain Caldwell's early return, he thought it advisable to enlarge the present committee. He stated that the duties of this committee would be to keep in touch with the shipyards throughout the country and to give them every assistance possible in order to push the work in the shipyards as far as allowed by the Classification Societies. The chairman thought that one man, preferably a resident of each district, would be responsible to the district officer in that

district as well as to this committee, and who would keep in touch with both the district office and this committee should be appointed as a member.

Discussion followed as to the proper chairman for this sub-committee.

Mr. Rushmore then suggested that the matter of this appointment be left to the chairman of the Electric Welding Committee. This was seconded by Mr. Henderson and accepted by all.

The next matter brought up for discussion was Mr. Henderson's resolution regarding an entirely electrically welded ship.

In regard to this resolution, Chairman Adams stated that he had been able to see Admiral Bowles and Mr. Cox, and that they both recommended that the question of building an entirely electrically welded ship be held up until the Design Committee has had time to present definite recommendations. Mr. Cox also stated that it would be very desirable in this connection to co-operate with Mr. Prior, who is head of the Technical Committee of the Emergency Fleet Corporation on the design end. Mr. Prior's name was added to the Ship Design Committee.

Mr. Bonner offered his patented design of an electrically welded ship to the committee for its use. Mr. Rushmore made a motion that the committee accept with thanks Mr. Bonner's design. This was seconded and accepted.

Chairman Adams then called for reports of work done by the sub-committees.

Executive Committee, C. A. Adams, Chairman.

Chairman Adams reported that in addition to the information sent to committee members, letters were sent to shipbuilders and electric welding concerns for their co-operation and assuring them of the committee's assistance. This letter is reproduced in Section H.

Approval of Tests Committee, E. A. Stevens, Chairman.

Mr. Stevens reported that a list of the parts which the Classification Societies have approved was made up and that same would be added to from time to time.

Chairman Adams asked this committee to outline such tests as would convince the Classification Societies as to the suitability of electric welding in other parts of the ship than those already approved.

Equipment and Power Committee, W. I. Merrill, Chairman.

Mr. Merrill read two letters drafted by him to be sent out, one to the shipyards and the other to manufacturers asking for

information. These letters were submitted to the members of his committee for their approval before they were sent out.

Research Committee, H. M. Hobart, Chairman.

Mr. Hobart said that a large amount of work had been done by the members of his committee but that one member was not aware of what the other had been doing. Therefore, he would like all members of his committee to submit reports of their work so that they could be compiled and submitted to all the members, as well as to the shipyards, manufacturers and the Navy Department. Captain Caldwell said he expected to have his report finished by the end of this week.

Mr. Hobart asked to have some changes made in the outline of his work as incorporated in the minutes of the second meeting as follows: Leave out No. 8, and allow this work to be carried on by Mr. Lachman. Chairman Adams advised that Mr. Lachman was already doing this work. Regarding "Safety," he would like to have Mr. MacNary's co-operation in this part of the work.

Training Committee, E. E. MacNary, Chairman.

Mr. MacNary reported that the General Electric Company had already set up facilities for training arc welders and the Quasi Arc Weltrode Co. was doing the same and that equipment had been ordered to be set up at Hog Island for 40 men to be trained at a time. He said the great need now was for a propaganda to the shipyards in order that they will send men to be trained.

Mr. Bonner told of the plans of his company for training welders as outlined in his letter to Chairman Adams.

Motion was then made to call a meeting of the Committee on Ship Design for Sunday, April 14th, at 9 A. M., in Mr. Prior's office of the Emergency Fleet Corporation, Room 841, Munsey Bldg., Washington, D. C. This motion was seconded and approved by all.

It was then agreed that the date of the meeting of the Electric Welding Committee would not be set until after the meeting of the sub-committee on Ship Design.

Meeting adjourned at 12.40.

Respectfully submitted,

C. A. ADAMS, Chairman.

E. A. STEVENS, Jr., Secretary.

SECTION D

RECOMMENDATIONS BY NAVAL CONSTRUCTOR KNOX.

Mr. David B. Rushmore,
American Institute of Electrical Engineers,
29 West 39th Street, New York City.

Dear Sir:—

Pursuant to your wishes at the last session of the Program Committee of the main Welding Committee, I beg to submit the following suggestions which are also concurred in by Mr. Ewertz.

The sole object of the committee is, by the introduction of electrical and mechanical devices not now generally used in shipbuilding, to increase the rapidity of merchant and warship construction and to utilize as far as possible the services of labor not now employed in the fabrication of ships or other war accessories.

It must be borne in mind, however, at the outset that a committee composed of members having other paramount duties cannot, in any case, produce the desired results, and the immediate employment of experts in the various activities is essential.

The means to be employed are primarily by the introduction of electric arc and spot welding to ship fabrication by

(a) Authorizing immediately the application of such welding to many parts of ships now under way or designed.

(b) The design with a view of early construction, of a merchant ship and destroyer in which welding is to be employed throughout in lieu of riveting, wherever safe and economical in speed, cost, weight.

(c) The very extensive substitution of welding for riveting in one or more standardized merchant ships and warships as a working demonstration of the utility of the process, and as development for future design.

(d) The providing of men and equipment for carrying out the foregoing.

(e) The immediate research into the practical application of ship welding including the tabulation of existing data and the amplification of tests, also the development of instructions for welders and specifications for machines and accessories

In order to best execute the program above proposed, I suggest the division of the Main Committee into sub-committees as follows: (I hesitate to suggest the membership of committees but am indicating in some cases present assignments).

1. **Executive Committee**—Messrs. Adams, Rushmore, Stevens and Knox.

To be in effect the Committee on Welding with authority to act for the Main Committee and in whom is vested all executive authority with full power to recommend to the Fleet Corporation and, in whatever degree is granted, to be the sole Fleet Corporation executive authority on the entire subject of ship welding.

The one executive committee should be backed by five staff sub-committees for technical information but without executive authority as follows:

2. **Ship Design**—Messrs. Ewertz, Knox, Stevens, etc.

(a) The general adaptation of spot and arc welding to ships' structures and all matters of ship design and fabrication incident thereto.

(b) The immediate publication for the benefit of shipbuilders, and, with the approval of marine classification societies, of those portions of a ship's structure to which welding may be applied without further investigation.

(c) The recommendation in detail of the application of arc and spot welding to at least one standardized merchant ship and one warship so that these vessels may be immediately built as demonstrations of the process and in order to further develop the design of completely welded ships.

(d) The design of a merchant vessel and warship along present standardized lines, structurally modified, where safe and economical, for welding throughout.

(e) Co-operation with the other sub-committees in the modification of welding practice to ship needs and the development of special equipment and devices for ship construction.

3. **Equipment and Power Supply**—Messrs. Merrill, Hornor, etc.

(a) A general survey of existing welding equipment, both arc and resistance in shipyards with the view to ascertaining the amount available, in service or on order.

(b) The study of how much such equipment is available in other non-essential industries.

(c) Investigation of producers to see the sources available and capacities of manufacturers for making welding equipment, both machines and accessories.

(d) A study into the probable needs for equipment to keep pace with the development of the technique now and in the future, also the commandeering (through the Executive Committee) or reassignment of all equipment.

(e) A study of the electric power generating facilities at shipyards as to generator capacity for future development, transformer and line capacity where power is bought—also capacity of central plants from which purchased.

(f) Portable leads—Specifications and Standardization.

4. **Training and Personnel**—Mr. MacNary.

(a) Establishment, after investigation, of standard instruction methods at all plants.

(b) Introduction and instruction of classes of labor not now used in military necessities, particularly women.

(c) A study of present and future demands for welders and ways and means of recruiting, etc.

(d) The construction of special training schools for welders.

5. **Research**—Messrs. Hobart, Nelson, etc.

(a) Development of standard nomenclature for arc and spot welds of all types of equipment used in welding. Rating of spot welders.

(b) The classification and tabulation for practical reference of all available existing data on the strength and other properties of welded joints in structural steel.

(c) The institution of additional tests found necessary or as requested by sub-committee on design. This study for example should include the test of welds made under identical conditions changing only one variable.

Among many other problems the following at once suggest themselves for arc welding alone:

(1) Best make of machine or principle of control.
(2) Chemical properties of electrode.
(3) Coating for electrodes.
(4) Best bare vs. best coated electrodes.
(5) Coated electrode A. C. vs. D. C.
(6) Flat, vertical (up and down) horizontal, and overhead welds.
(7) Effects of wind, rain, etc., on strength of weld.
(8) Proper values of current, voltage, electrode size, etc., for different weights of plates and different types of weld.
(9) Necessary current regulation and voltage characteristics leading to the simplest welding equipment suitable for ship welding.
(10) Similar tests on spot welded joints and welding machines.

(d) From the above suggested tests the compilation of

working rules for designers and operators, also the development of the simplest possible machines and the standardization of specifications for welding wire, bare and coated, etc., etc.

(e) The determination of average speeds of welding under favorable conditions with different weights of plate, sizes of electrode wire, position of work, etc. These data to be used in determining the proficiency of welders, estimates of costs, piece work rates, etc.

(f) Tests on strength of welds under repeated stresses, resistance to corrosion, etc., also the determination as far as experimentally possible of how poor an arc weld can be made between steel plates under the limitations that the machine is good, the electrode good, the electrical conditions correct for the work in hand, the speed reasonable and that the weld passes visual inspection.

(g) **Safety.** The study and standardization of eye protection shields, gloves, aprons, screens, etc. The U. S. Employees Compensation Committee has already devoted much time to this subject.

(h) The study and development of automatic seam welding machines, arc and resistance, the development of holding-on magnets, etc.

6. **Publicity.**

The dissemination, as directed by the Executive Committee, by letter and bulletin (public or confidential) to shipbuilders and others, such information as may become available, together with all rules, design points welding records, which may tend to broaden information or stimulate greater production.

(Signed) H. G. KNOX.

SECTION E

RECOMMENDATIONS BY MESSRS. EWERTZ AND KNOX FOR THE CONSTRUCTION OF STANDARDIZED SHIPS SUCH AS ONE OF THE SHIPS NOW BEING BUILT AT THE SUBMARINE BOAT CORPORATION. (5,000 tons.)

At the second meeting of the Electric Welding Committee, Messrs. Ewertz and Knox submitted the following proposal:

It is believed that a ship built on the transverse principle is more adaptable at the outset to welding than one of the Isherwood ships on the longitudinal principle. With this in view, the following recommendations are submitted for the construction immediately of one standardized Merchant Ship as follows:

1. Omit all staples.
2. Weld decks to shell omitting all cement, etc. Notch inner channel flanges where cut by decks and weld.
3. Butt weld seams and butts of vertical shell (above turn of bilge) eliminating all laps, liners, joggling, straps, etc. Rivet plates to frames.
4. Butt weld seams and butts of deck, etc., as for shell.
5. Spot or arc weld brackets to one member (beam or frame) in shop, and arc weld to other member in ship.
6. Spot weld floor plates to frames and reverse frames in shop, also clips.
7. Spot or arc weld cargo batten clips and other similar fittings.
8. Weld all deck erections, smoke pipes, uptakes, ventilators, ducts, coamings for hatches and manholes, door frames, separately built tanks, lockers and racks and all miscellaneous non-strength members.
9. Masts, booms, shaft and pipe tunnels, and similar cylindrical work, now in two pieces, strapped, to be welded throughout omitting straps. Cast steel fittings should be welded to plates.
10. Recommend the use of welding for all oil tanks even in conjunction with riveting.
11. Swash plates may be tack welded to decks and bulkheads and flanges omitted.
12. Flanges on all steel pipe and tubing to be welded. Stanchions, stanchion heads and heels, pipe railing, etc.

SECTION F

CAPTAIN CALDWELL'S REPORT TO WELDING COMMITTEE ON:

(1) Propaganda in Britain.
(2) Training of Welding Operators.
(3) Preparation of Work for Welding.

REPORT TO ELECTRIC WELDING COMMITTEE. EMERGENCY FLEET CORPORATION.
March 25, 1918.

As desired at your meeting on the 23rd inst., I submit the following brief outline of the means adopted to extend the use of electric welding in Britain with particulars relative to the system of training operators for application of the arc process.

(1) PROPAGANDA IN BRITAIN

Introduction.

During 1917 special action was necessary by the British Admiralty to provide adequate supplies of oxygen and carbide for welding and cutting.

In July I was instructed to investigate other available methods of welding with a view to easing the existing condition by substitution of oxy-acetylene.

Formation of Committee.

Subsequently an oxy-acetylene committee was formed to regulate the supply of carbide and oxygen and develop the extension of other methods of welding. This Interdepartmental Committee was representative of all existing Government Departments and comprised two executive sections with duties as under:

1. **Carbide Section**—to arrange for the importation, production, allocation and distribution of carbide.
2. **Oxygen and Electric Welding Section**—to deal with the production and allocation of oxygen—also of matters appertaining to electric welding and cutting.

Powers Vested in the Committee.

Orders were published by the Admiralty and Ministry of Munitions under the Defence of the Realm Act which empowered the committee to take over the control of carbide and oxygen, these executive sections being operated by an officer attached to the Government Department most dependent upon adequate supplies of materials.

Due to the fact that Admiralty requirements for oxygen were fully 60 per cent in excess of the aggregate of other demands it was realized that the welding situation was most vital, especially as considerable supplies were necessary for cutting shipplates, etc.

Procedure of Electric Welding Section.

Descriptive information and comparative data relative to the use of the electric arc for welding and cutting purposes was prepared and arrangements were made for these particulars being distributed amongst firms engaged on welding work.

As regards cutting it is of interest that successful results were obtained at Admiralty Dockyards and elsewhere where it was found that with the carbon arc even though the operation of electric cutting or melting took a longer time to perform than with the gas blow-pipe the cost was in many cases appreciably less.

Firms were encouraged to advise the section when electric welding equipments and accessories were ordered for manufacturers, and assistance was given to obtain for them a high degree of priority to hasten delivery.

A staff of five officers (Area Superintendents) and twenty-four demonstrators was appointed to promote economy in gas welding and advocate electric welding wherever possible. These men required to be trained in the first instance, and to accomplish this they were divided into five groups, each of which attended at the works of selected firms where different systems using carbon, bare-metal and flux-covered electrodes were in successful service.

After two weeks' practical work with the several firms the groups were "changed over" until each received a general understanding of the several processes and the different methods of applications. During this period of instruction lectures

were given to the officers and men. Within two months these operators constituted a mobile gang of trained demonstrators who have since proved themselves very efficient and useful in the instructing of local labor at many factories, shipyards, etc., in the successful application of electric welding throughout the country.

The general procedure was to place one man at the disposal of each firm adopting electric welding for the first time, the intention being that he would remain there for two or three weeks when he was able to impart a vast amount of welding experience and up-to-date practice, besides assimilating new ideas himself and in this way attaining the best results for the successful extension of the process.

In considering the applications for such services it was decided to concentrate on providing a nucleus of skilled electric welders at the works engaged primarily in the manufacture of mines, bombs and other munitions. Thereafter similar assistance was given to the Naval Dockyards and firms engaged in shipbuilding and repair. Applications for the service of these skilled electric welding operators were continually received not only from the above quarters but also from the Government Departments interested in the output of the several firms.

The Area Superintendents were continually investigating the welding requirements in their respective districts and the section was then informed as to the places where electric welding could be most satisfactorily utilized.

Information of successful applications and developments of electric welding with data of tests and detail construction methods was distributed by the section which has always endeavored to keep in touch with the latest welding practice.

As the successful developments in electric welding became known as a result of the efforts of the section relative information on the subject was constantly applied for by the Government Departments and manufacturing firms. Each of these inquiries received careful attention and if considered advisable an officer visited the firm to advise as to the methods most suitable for the particular kind of work to be done and if desired helped in the selection of apparatus and discussed methods of electric power supply and distribution.

It may be mentioned that when advocating electric welding the importance of obtaining skilled operators was always emphasized whether they were required for repetition work where a sufficient degree of skill can be acquired in two or three weeks, or for a variety of repetition processes, and in the execution of repair work, these latter undertakings demanding an efficient tradesman's experience and judgment as well as an operator's skill.

(2) TRAINING OF WELDING OPERATORS

Instruction of Welders.

Until a few years ago electric arc welding was carried out by welding companies who generally confined themselves to the execution of repairs with a highly trained staff of operators.

The more general application of the system for use in the factory makes it necessary to devote considerable attention to the standardization of the methods of application and the training of workmen. Formerly every welder was more or less working out his own salvation as circumstances would allow which has lead to variation in the quality of the work depending on the nature of the plant and the skill of the operator.

Plant.

It frequently happens that welders reach a high degree of skill with the plant at their disposal but meet with failure in certain work owing to its inadequacy. As the plant to them represents the process of electric welding, electric welding stands condemned, where under proper conditions it would have shown to advantage.

Need for Scientific Training of Operators.

Clearly there is room here for scientific training. Electric welding is both a science and an art; the art is easily acquired as far as simple routine work is concerned, but the scientific side requires careful study. To begin with the unskilled workman or girl to be trained as a welder should be taught how to burn-down an electrode steadily and, as a rule, becomes proficient in about four days. Some simple welding operation is now selected and this stage of the training is complete. This obviously does not make an electric welder but it shows how easy it is for one to acquire the art of manipulating the electrode.

Technical Knowledge Essential.

The complete welder should make himself familiar with the elements of electricity, how it is generated, conducted and regulated—also know the melting points of the different irons and steels, and the changes which they undergo in the arc. He must also study expansion and contraction, and the preparation of the material to be welded. He should also be familiar with the changes which take place in the mechanical properties of the metal in and near the weld, and as a welder he should be expert in all the methods of depositing metal under varying conditions such as are met in actual practice. Fur-

ther he must know the exact current required for the different thicknesses of metal and the various sizes of electrodes with most suitable constituents of metal and slag covering.

Training Routine—General Remarks.

In the absence of any co-ordinated course of instruction in electric welding, the duty of providing the necessary instruction falls in unexpected places, and it not infrequently happens that the tuition provided is of the "Watch me do it" variety. This is quite good if the operator is expert, but it only touches the fringe of the subject.

Everything is new to a beginner and everything must therefore be explained. To begin with one might deal with the properties of electricity; and explain how it is this energy which is transformed by the arc into heat thus becomes available for welding. Before reaching the arc it is usual for the current to pass through a regulating resistance adjacent to the operator, where an ammeter is also fixed. The exact quantity of current used is indicated on the ammeter and this should be checked occasionally during the course of the work as the resistance heats up during use when less current passes, necessitating occasional adjustment in order to ensure the use of the correct amount of current Depending on the source of electricity supply, instruction will necessarily vary. It is important to limit the amount of current to prevent the deposited metal being crystalline. The methods of making contact with the work should next be studied, always keeping in mind that loose contacts mean bad work. When the end of the negative wire is stranded, the strands should be carefully flattened out and clamped firmly to the work so that every part of the strand makes contact. If a loose contact is made the current must pass through a few strands and the resistance thus created prevents the use of proper current. When small parts are being welded care should be taken to secure good contact by clamping them together.

Stage 1.

The beginner may now commence the art of welding. Some little time may be devoted to watching a good welder operating. He should then be provided with a pair of pliers and a pencil, and set to practicing the correct movements on paper. This paper record will clearly indicate when practice may be commenced with a real electrode. While practicing, a welding screen should be held in the free hand so that the manipulation of the screen may also be learned. The opportunity should also be taken to emphasize the use of the welding screen on all occasions and under no circumstances to allow the arc light to enter the eyes. The learner is now ready to manipulate a real electrode. Show him exactly how

to proceed by placing an electrode in the holder, adjusting the resistance and closing the switch, then burn down a little of the electrode and tell him to take the reading on the ammeter. If he does this correctly, give him the electrode holder and get him to strike up the arc, steadying his hand meanwhile and running down a little metal each time. As he acquires the touch he needs less assistance and once started will manage to burn down the electrode by himself.

Stage 2.

The next step is to deposit a continuous layer of metal which on cleaning up will show a regular deposition. This done, he takes up the study of straight seam welding on thin plate—say—No. 8 gauge. The plate is cut in strips about 2" wide and these are welded together. The first few runs are done on the flat bench, separating the plates about 1/10", tacking at the bottom and commencing the weld at the top of the seam. This is repeated until a regular seam about ¼" wide can be made. The plates are now raised so that the line of the weld is unsupported and the above experiment repeated until a weld showing complete penetration can be made. The best of these welds should be examined carefully and afterwards broken. Concave depressions where the arc has broken indicate bad metal beneath, and crystalline patches in the fracture indicate where too long an arc has been used. The presence of blowholes indicates the use of excessive current or the fusion of too much metal at that part.

Blowholes are the bugbear of all conscientious welders and are not by any means confined to electrical welds. They are obviously due to the formation of gas when the metal is near to its melting point. The principal constituent of this gas is probably carbon Monoxide formed by the union of the Carbon of the Steel with occluded or chemical combined Oxygen. These bubbles of gas tend to rise and so form pipes in the weld. Such blowholes may be quite numerous and then seriously impair the strength of the weld. Unfortunately the appearance of such welds at the surface does not indicate the presence of blowholes beneath, and for this reason welders should make frequent test pieces to assure themselves that they can realize the correct conditions associated with the deposition of sound metal.

Stage 3.

The beginner should next study the welding of plates closely butted together. Here he will produce an apparently good weld, which however, breaks easily under shock. The explanation here is that the apparent butt weld is due to the fusion of the oxide of iron formed by the excessive heating and all strength is at the surface. Experiments may now be

extended to thicker plate. Thicknesses above ¼" are Veed right to the bottom. This is very important as otherwise the weld will not go right through. One-quarter-inch is also the limit for welding in one layer, the amount to be added in subsequent layers being the reciprocal of the gauge of the electrode in inches, e.g., a No. 4 electrode will build up ¼" at a time. This rule only applies to mild steel electrodes. In welding thick plates great care would be taken to ensure the complete fusion at the bottom and sides of each added layer, and it is further necessary to avoid large pools of metal if blowholes are to be avoided.

Stage 4.

Some knowledge should now have been obtained by the instructor as to the general standard of proficiency that the individual student is capable of and it will, therefore, be possible to classify the welder as one or other of the following:

(A)—Proficient.
(B)—Skilled.
(C)—Superior.
(D)—Very Superior.

Each of these groups should be delegated to perform a certain class of welding, according to their skill and ability so that they may become expert in such work. It is suggested that in addition to differentiating between those sufficiently skilled to tack or apply the first or second layers of added metal in repetition work, the welders should become specialists in one or other of the following operations:

1.—Flat-welding.
    (a) downward.
    (b) upward.
2.—Horizontal welding.
3.—Vertical welding.

The above recommendations will generally apply to any form of electric arc welding but they particularly refer to the use of systems employing metal rod electrodes covered with a flux coating.

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(3) PREPARATION OF WORK FOR WELDING

There are a few general rules for preparing work for welding, and a good many special applications of those rules.

The surfaces to be welded, i. e., which have to be united to each other or to added welding metal must be clean, free from scale, rust and any other foreign matter. Freshly cut or filed

surfaces, cut or filed without lubricant are the ideal. The skin of castings or the scale of forged or rolled material must be removed. In the case of electric butt welding the opposed surfaces should be fitted so that there will be uniform contact over the whole area.

The effect of expansion and contraction must be considered and allowed for. If contraction takes place across the line of weld the welding metal which is the hottest and weakest part is likely to pull asunder. This is particularly important in repair work where the parts to be united form part of a rigid structure. To avoid this, preheating of the work may be necessary, so that the expansion due to the welding heat is equalized by general heating of the whole structure. This precaution is the more necessary with increased thickness and length of the weld, which involve greater heating of the adjacent parts. It is of greater importance with gas welding than electric welding, becauses the heating is more diffused and a greater extent of metal is heated by the blowpipe flame than by the more localized electric heating. In extremely heavy work preheating may be advantageously carried to a fairly high temperature, economizing in the consumption of the welding gas points can be worked out experimentally and provided for in preparing the material and arranging the apparatus and operations, leaving as little as possible to the judgment of operator.

In repair work every job varies, improvised arrangements and fixtures are unavoidable, and experience and judgment are indispensable. The cleaning of work that has to be repaired **in situ** is not always easy. A pneumatic sand blast apparatus is a useful adjunct to portable welding plants for such work, and is applicable to cleaning large work generally. Where parts have to be repaired to exact dimensions, e. g., in welding a broken crank shaft to correct journal centres the parts should be fixed to gauge marks with a proper allowance for contraction during cooling, and be free to contract after welding without putting stress across the weld. The allowance to be made is necessarily more a question of judgment than of calculation.

Fixing of the parts to be united so that there shall be no relative movement during the process is very important. In doing this the possibility of the parts springing from the effect of the heat expansion has to be considered and provided for. This again is of special importance in repair work where it is important that broken parts shall be restored to their exact former position, or at least be near enough to permit of rectification by tooling. In addition to fixing support should be provided along the line of weld, especially in thin work, as the heated metal is weak and may fall away or buckle by its own weight and by expansion without it. The support for

such thin work should be fairly massive, to conduct the heat from the work, and reduce the liability to melt holes in it.

In the case of long welds the edges to be united should not be quite parallel but splayed open slightly from the beginning of the weld. The expansion of the first welded part will close up the opening as the welding advances. Otherwise the edges towards the end will butt or overlap before the seam is finished.

In all but the thinnest work the edges should be chamfered or bevelled, forming a V open at the top. In very thick work, which has to be welded from both sides, the chamfering should be done on both sides, so that the two welds meet in the centre of the thickness.

In very thin sheet the opposing edges may be turned up at right angles, or the edges may be lapped one over the other. In overlapping thick plates, such as boiler lap joints, the "landing edge" must be chamfered off, as it is difficult to weld into the right angle formed by the square cut edge of a thick plate.

SECTION G

CIRCULAR LETTER FROM THE "EQUIPMENT AND POWER" SUB-COMMITTEE OF THE ELECTRIC WELDING COMMITTEE TO ALL SHIP-YARDS.

New York, April, 1918.

Gentlemen:

The above named committee has been entrusted with the task of pushing the application of electric welding to shipbuilding wherever it proves economical of time, labor and material and as far as it is permitted by the Classification Society. A list of parts approved for electric welding by the Classification Societies is enclosed herewith. It is our belief and the experience of those shipbuilders who have adopted this method of construction that it will mean a very considerable saving in time, labor and material.

Will you kindly send us at your early convenience a statement as to the extent to which you are now employing either electric or gas welding methods, together with the type, size and number of equipment in use and on order; also as to the number of equipment necessary to further apply this method to all of those approved parts given on the enclosed list.

We will send you shortly copies of various reports and test data relating to this subject, including a full report of work in this field which has been carried out by the British Admiralty and Lloyds Register of Shipping in Great Britain.

Several shipbuilding yards in this country have already carried out electric welding work to a considerable extent and they have found it eminently successful.

The ultimate aim of the committee is to save time in the building of ships and thus to forward the shipbuilding program. In addition to stimulating interest among the shipbuilders, we are starting schools for arc welders and aiding those already established. We are also preparing to conduct additional tests to convince the responsible authorities of the suitability of this application on other portions of the ship than those where it is now allowed by the Classification Societies.

In addition to the work in this line which might be referred to as laboratory tests, preparations are being made for the construction of a 50-foot section of a standard 9,600-ton merchant ship at the Federal Shipbuilding Corporation, Port of Newark. This demonstration is in charge of Mr. Arthur J.

Mason, of the Emergency Fleet Corporation. The present plan is to tack the plates together with a large portable spot welder and to arc weld all seams. When completed, this section will be sealed up at the ends and tested under hydraulic pressure.

This experiment is intended not only to demonstrate the practicability of this method of construction, but also to develop methods of handling the plates preparatory to welding and order of assembly adapted thereto.

Following this demonstration a committee on design has been appointed for the purpose of preparing a design of a standard ship so modified as to adapt it most readily to electric welding methods, and so modified as to bring about the greatest saving of material as well as time.

Progress in all of these activities will be reported to you at frequent intervals and the committee stands ready to give you any assistance within its power.

A committee is also making an inventory of the available production capacity of electric welding apparatus in this country, as it is likely that this capacity will be in full demand.

In case your corporation has more than one plant, will you kindly see that a copy of this letter is transmitted to the proper authority in each plant?

A prompt reply will be appreciated.

Very truly yours,

C. A. ADAMS, Chairman,

E. A. STEVENS, Secretary.

SECTION H

CIRCULAR LETTER SENT TO MANUFACTURERS OF ELECTRIC WELDING APPARATUS.

New York, April, 1918.

Gentlemen:

The above named committee was appointed by the Emergency Fleet Corporation to do all in their power to hasten the shipbuilding program by the introduction of electric welding methods wherever such introduction promises the saving of time.

A study of the conditions in most of our large shipyards shows that there is in nearly every case considerable room for the extension of electric welding without exceeding the limitations imposed by the Classification Societies (Lloyds and the American Bureau of Shipping).

In order to extend this application as rapidly as possible we are seeking the co-operation of all bodies interested in this field of activity. Will you, therefore, kindly send us at your earliest convenience all information at your disposal under the following headings:

(1) Description of, together with any comments you may wish to make on, the particular methods and apparatus which you employ or manufacture.

(2) All available data concerning the cost of this apparatus including the cost of electrodes.

(3) Data concerning the power required and the probable speed in feet per hour when welding a full strength fillet along the seam of overlapping ½" plates; ditto for ⅝" and ¾" plates.

(4) Any information you may have as to the best type of welded joints for the shell plating of a ship.

(5) Any test data (with full information as to the type of weld, drawings or photographs if possible) in regard to the strength and other qualities of welded joints. In this connection it is particularly desirable to get all the information available as to the effect of vibration or alternating stresses upon such joints.

(6) A description of the various kinds of work to which you have successfully applied electric welding, particularly in connection with shipbuilding.

(7) A full statement of the successes and failures in such application with explanation of the failures when possible.

(8) Any other information which will throw light on the subject at hand.

We realize that this is asking a good deal of your time and

that it may involve revealing what you may consider inside information, but we feel that the emergency warrants the cordial co-operation of every one that can render any assistance. We also wish to assure you that this information will be used only in our common interest.

It is our hope and expectation that electric welding methods will be rapidly extended beyond those parts of the ship now approved by the Classification Societies. A list of these approved parts is herewith enclosed.

Very sincerely yours,

C. A. ADAMS, Chairman.

Report No. 5

DESCRIPTION OF THE EWERTZ TYPE OF ELECTRIC WELDED SHIP

This invention relates to an improved vessel of the type known as "barge," the object of the invention being to provide a vessel of large carrying capacity and made of channeled or flanged steel, which can be manufactured at a comparatively small cost and in a comparatively short time, the outer shell of the vessel being formed of metal channel or flanged plates, preferably steel, extending from the bow to the stern of the vessel and with the flanges on the channels projecting inwardly, said channel plates constituting a complete watertight shell, the same being electrically welded together.

In addition thereto the invention contemplates reinforcing and strengthening said channel plate shell by means of longitudinally extending keelsons on the bottom of the vessel and by means of longitudinally extending side stringers on the opposite sides of the vessel, and furthermore, said vessel is strengthened by means of transversely extending floor plates on the bottom of said vessel and vertically disposed plates extending transversely of said shell plates on the opposite sides of said vessel. All of the plates referred to are preferably flanged. The deck is also formed of channel plates strengthened by transversely extending flanged web plates. Flanged brackets are also interposed where desirable to lend strength to the structure.

It will be understood that the hull of the vessel is constructed entirely of flanged metal plates electrically welded together so that in the completed structure the plates are practically integral with each other, and by this construction a very strong and light vessel is obtained at a comparatively small expense. The flanged plates are formed of sheet metal rolled out in a manner well known to those skilled in this art. Great quantities of the plates can be produced in a short time and with absolute accuracy.

While the vessel of my invention is particularly adapted to that type of vessels known as "barges," I do not wish to be understood as limiting my invention to any particular type of vessel, as the same may be used in the construction of other types of vessels than barges with equally desirable results.

The invention consists of a vessel formed as hereinafter described and particularly as set forth in the claims.

Referring to the drawings (see end of report):

Fig. 1 is a side elevation of a vessel constructed in accordance with my invention.

Fig. 2 is a somewhat diagrammatic plan view of the same, the masts, booms and rigging being omitted.

Fig. 3 is an enlarged sectional elevation taken on line 3-3 of Fig. 1.

Fig. 4 is a sectional elevation taken on line 4-4 of Fig. 3.

Fig. 5 is a sectional elevation taken on line 5-5, Fig. 3.

Fig. 6 is a sectional plan taken on line 6-6, Fig. 3.

Fig. 7 is a detail section on line 7-7 of Fig. 3, and illustrates the construction of a joint between the shell and web frame at this point, the same construction of joints being applicable to joints between web frames and stringers, floor plates and keelsons, web plates to hatch coaming and bulwarks to brackets and the like.

Fig. 8 is a detail section taken at line 8-8, Fig. 5, and illustrates the construction of joint between flanged shell plates and keelsons and between stringers and shell plates.

Fig. 9 is a detail section taken at line 9-9, Fig. 5, and illustrates the construction of joint between flanged plates, such, for example, as the shell plates.

Fig. 10 is a detail section taken on line 10-10, Fig. 3, and illustrates the construction of joint between stringers and web frames and the floor plates and keelsons.

Fig. 11 is a detail section taken at line 11-11, Fig. 1, and illustrates the construction at the stern to form a space for the rudder.

Fig. 12 is a detail section illustrating a modified form of joint for the shell plating at the deck, stringers and keelsons, being a modified form of the joint illustrated in Fig. 8.

Fig. 13 is a transverse section of one of the masts taken on line 13-13, Fig. 2.

Fig. 14 is a detail section illustrating a modified form of joint for the shell plating at the deck, stringers and keelsons.

Fig. 15 is a transverse section illustrating a modified form of joint and shell plates.

Fig. 16 is a detail section taken on line 16-16, Fig. 4, illustrating the joint between the adjacent ends of two shell plates.

Fig. 17 is a sectional elevation taken on line 17-17, Fig. 1.

Fig. 18 is a sectional elevation taken on line 18-18, Fig. 17.

Fig. 19 is a section plan taken on line 19-19, Fig. 17.

Like numerals refer to like parts throughout the several views of the drawings.

In the drawings, the outer shell 15 of the vessel consists of a plurality of channel plates 16, the flanges 16' on said plates extending inwardly and being fastened securely together to

make water-tight joints by electric welding. The channel plates which extend along the sides and bottom of the vessel each consists of one continuous piece extending from the bow to the stern of the vessel. Each of these channel plates is, in the completed structure, a continuous piece, although they are each made from a plurality of sections of channel plate with their ends butted and electrically welded together, and the word "continuous" throughout the specification and claims, where it applies to shell plates, keelsons, side stringers and deck plates, is used in this sense, viz.: that the piece is continuous although formed of a plurality of pieces welded together.

In Fig. 16 is illustrated two sections of a channel plate 16 with their butted ends electrically welded together at 73.

A continuous flanged keelson 17 extends from the bow to the stern of the vessel and projects between the flanges of two adjacent channel plates 16 to which it is electrically welded in a manner illustrated in Figs. 3 and 8. This keelson is also formed of a plurality of flanged metal plates with their ends butted and welded together to form one continuous keelson. The keelson 17 has a horizontal flange 18 along its upper edge and is still further strengthened by an angle plate 19 which is welded thereto.

Similar continuous keelson plates 20 are provided at each side of the vessel and between the continuous keelsons 17 and 20 are provided intercostal keelsons 21. Each of said keelsons has a flange extending along its upper edge and is interposed, at its lower edge portion, between the flanges of adjacent channel shell plates.

In order to still further strengthen the bottom of the vessel, floor plates 22 are provided which extend transversely of the keelsons and are electrically welded along their lower edges to the channel plates 16 and at their ends are also welded to the keelsons where they abut against or intersect the same. The floor plates 22 have a horizontal flange 23 thereon.

Each side of the vessel is strengthened by means of a continuous side stringer 24 and intercostal side stringers 25. Said side stringers are provided with flanges along their inner edges and their outer edge portions project between flanges on adjacent shell flanged plates 16 and are electrically welded thereto, as illustrated in Figs. 3 and 8.

The sides of the vessel are still further strengthened by means of flanged web frames 26 and 27. The web frames are welded along their edges to the channel shell plates and are also welded at their ends to the side stringers.

The deck is formed by a plurality of continuous channel metal plates 28, the flanges on said deck plates extending downwardly and being welded together. The deck is strength-

ened by means of web plates 29 which are welded along their upper edges to the inner faces of the channel deck plates. Said web plates 29 are also welded at one end to the flanged side web frames 26 and at the opposite end to a channel plate 30 which extends above the deck to form a coaming 31. The coaming has a flat bar 32 welded to the inner face thereof adjacent its upper edge to support the hatch. Where the coaming does not occur, the web plates which support the deck extend entirely across from one side of the deck to the other and are welded at their ends to the flanged side web frames 26.

The web plates 28 and flanged web frames 26 are further strengthened and joined together by means of flanged brackets 33, which are welded to said web plates and web frames along their meeting edges.

The bulwarks 34 are also formed of channel plates extending the full length of the vessel from the bow to the stern thereof and are strengthened laterally by means of flanged bulwark brackets 35, which are welded to the bulwark plates and to the deck plates where they abut against the same.

The manner of welding the edge of the web frame 27 to the shell plate 16 is illustrated in detail in Fig. 7, in which 36 is the welded joint. This particular construction of joint is to be employed between the shell plates 16 and web frames 26, 27 and also where the web frames 26, 27 are welded to the stringers 24, 25 and the floor plates 22 to the keelsons 17, 20, 21, and the web plates 29 to the hatch coamings 31, the bulwarks 34 to the brackets 35 and in any joint where the edge of one plate abuts against the face of another plate.

In Fig. 8 is illustrated in detail the form of joint employed between the flanged shell plates 16 and the side stringers 24, 25, and also between the shell plates 16 and the keelsons 17, 20 and 21, or in any joint where it is desired to join together flanged shell plates with another plate interposed between the flanges of said shell plates.

As illustrated in Fig. 8 a hole 37 is provided which extends through the flanges of the shell plates 16 and through the stringer 25. This hole is to provide means for temporarily fastening the plates 16 and stringer 25 together prior to the welding operation. These holes can be plugged and welded subsequently to the joint welding operation where a watertight joint is required. The shell plates 16 and the stringer 25 are welded together at 38 and 39, as illustrated in Fig. 8.

The construction of joint between the flanged plates, such as two of the shell plates 16, is illustrated in Fig. 9, in which the welded joints are illustrated in Fig. 9, in which the welded joints are illustrated at 40 and 41. For temporarily fastening the plates together prior to the welding operation, the flanges of the plates 16 are provided with holes 42 through which a

bolt may be passed to temporarily join the flanges of the shell plates together during the welding operation.

In Fig. 10 is illustrated the construction of welded joint 43, where the end of a floor plate 22 is welded to one side of a keelson 20 and the edge of a web frame 27 is welded to the opposite side of said keelson. This construction of joint can be employed wherever the edges of two plates abut against the opposite faces of another plate interposed between such edges.

In Fig. 11 the construction at the stern is illustrated in which one of the channel plates 16 is welded at 44 and 45 to the upper face of a shelf plate 46 and another channel plate 16 is welded at 47 and 48 to the under face of said shelf plate 46. These channel plates and the shelf plate are also provided with holes 49 and 50, whereby the channel shell plates and the shelf plate may be temporarily attached to each other prior to the welding operation by means of bolts, the bolts after the welding operation being removed and the holes 49 and 50 being plugged and welded in order to insure watertight construction.

It will be seen that the channel shell plates above the shelf plate 46 extend outwardly beyond the channel shell plates beneath the shelf plate 46 at the stern of the vessel to provide a space 51, Figs. 1 and 11, to receive the rudder 52, which is pivotally mounted at 53 upon a frame 66 fastened between the shell plates 16 where they are brought together at the stern of the boat and said rudder is operated by mechanism well known to those skilled in this art.

Instead of the shell plates 16 having flanges 16′ at the top and bottom edges thereof, said shell plates may be constructed with a flange at the bottom edge thereof only, as illustrated in Fig. 12, in which the shell plate 54 has an inwardly extending flange 55 at the bottom thereof and the shell plate 54′ has no flange at its upper edge. An intercostal side stringer 56 is interposed between the adjacent edges of the shell plates 54 and 54′ and said stringer and plates are welded together at 57, as seen in Fig. 12, and the flange 55 is welded to the stringer 56 at 58, this being a modified construction of the form of welded joint illustrated in Fig. 8.

Another modified construction is illustrated in Fig. 14 in which the shell plate 67 has no flange at the bottom edge thereof. The shell plate 68 has a flange 69 at the top thereof and a side stringer 70 is interposed between the lower edge of the shell plate 67 and the flange 69 of the plate 68, the parts being electrically welded together at the joints 71 and 72.

In Fig. 15 a modified construction of joint between two adjacent flanged shell plates is illustrated in which the shell plate 74 has a flange 75 along its lower edge and the upper edge of the shell plate 76 has no flange thereon. The adjacent

upper and lower edges of the shell plates 74 and 76 are shown as electrically welded together at the joint 77.

The vessel is preferably subdivided into compartments by a plurality of bulkheads 78. The construction of said bulkheads is illustrated in Figs. 17, 18 and 19. Each of the bulkheads consists of a plurality of flanged plates 79, 80, 81, 82 and 83 on each side of the keelson 17, said bulkheads extending entirely across the vessel and being welded to the shell plates 16 of the vessel, and also to the channel plates forming the outer shell of the vessel.

The bulkheads are stiffened laterally thereof by horizontal flanged plates 85 and 86 which extend horizontally across the bulkhead in alignment with the side stringers 24 and 25, respectively. Said stiffeners are welded to the vertically extending plates 79, 80, 81, 82 and 83 and at their ends are welded to the side stringers 24 and 25. It will be understood further that the bulkhead plates are welded to the keelsons, where they abut against the same and to the angle plate 19.

The flanges 84 on the plates forming the bulkheads extend vertically and are welded together. The bulkhead plates 79 are slotted to receive the keelsons 17, 21 and 20 and the flanges extending along the upper edges of said keelsons are cut away or slotted to allow the keelsons to enter the slits in the bulkhead plates. The flanges on the side stringers 24 and 25 are also cut to allow the bulkhead plates to pass thereon, said bulkhead plates being slotted to receive the side stringers. The horizontal flange on the angle plate 19 is also slotted where it intersects the bulkhead plates. The upper ends of the bulkhead plates are welded to the under faces of the deck plates 28.

The bulkhead plates are each preferably made of a plurality of flanged plates, their ends butted together and welded.

It will be seen that the bulkheads being welded to the bottom and side shell plates and to the deck plates of the vessel, and each bulkhead extending from side to side of the vessel, not only divide the vessel into compartments, but also greatly strengthen the same laterally.

The vessel is provided with masts 59 and booms 60, said masts and booms being preferably constructed as illustrated in Figs. 1 and 13, viz.: by two pieces of flanged plates 61 and 62, which are welded together at 63. Said masts and booms are still further strengthened by means of flat iron braces 64 which are welded at their ends at 65 to the flanged plates 61 and 62.

The different parts of the vessel hereinbefore described may be welded together either by a continuous welding joint or they may be welded together in spots, the welded spots

being about three inches apart. The preferred method of welding the parts together is that well known to those skilled in the art as "arc" welding.

In building the vessel hereinbefore described, the keelsons 17, 21 and 20, the channel plates 16 and the floor plates 22 are first bolted together and tied with ribbands extending longitudinally of the keelsons in a manner well known to those skilled in this art. The side web frames 27 and 26 and side stringers 24, 25 are next assembled, being joined together by bolts, and the shell plates temporarily affixed thereto by bolts. The different joints are welded together, as hereinbefore described, on the bottom and sides of the vessel, the final work being, so far as the hull is concerned, to assemble the web plates 29, the deck plates 28 and the channel plates 30 forming the coaming, all of these latter being temporarily bolted together and then welded as hereinbefore described.

In the foregoing specification the preferred construction has been described, but it is evident that without departing from the spirit of my invention the flanged shell plates may have their flanges bolted together, or to the stringers 24, 25 and keelsons 17, 20 and 21. In such case, however, the flanged plates 16 and the flanged keelsons and side stringers would be made in continuous pieces from a plurality of pieces by butting the ends together and electrically welding the same as hereinbefore described.

It will be seen from the foregoing specification that a watertight outer shell for a vessel is formed by a plurality of flanged sheet metal plates welded together, each of said sheet metal plates, preferably extending from the bow to the stern of the vessel, and that said watertight outer shell is strengthened laterally by means of keelsons along the bottom of the vessel, by means of plates extending transversely to said keelsons and side stringers, the whole being welded together to form a vessel of flanged sheet metal members practically integral with each other.

Furthermore, the bulkheads being formed of plates welded together and being welded around their edges to the flanged shell plates forming the sides and bottom of the vessel and to the deck plates, side stringers and keelsons form watertight compartments, so that any damage to the hull of the vessel, whereby a hole is made through the shell into one of the compartments, would leave the other compartments intact.

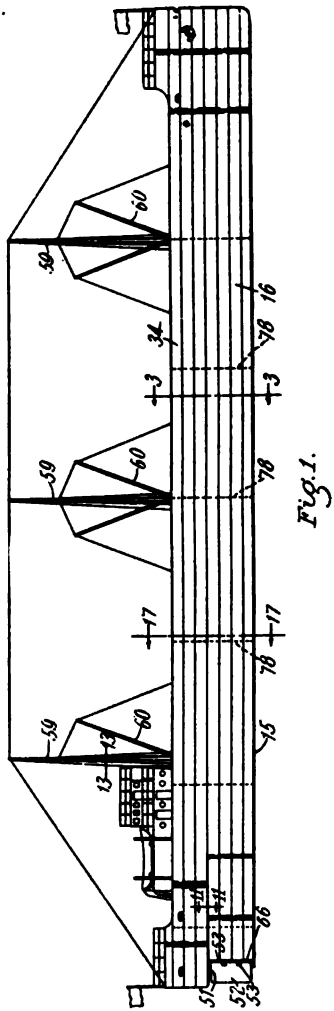
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Fig. 1.

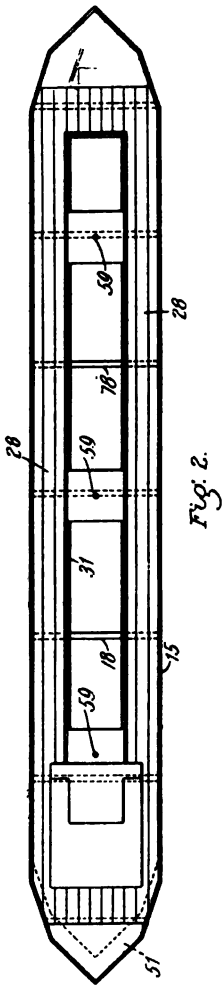
1
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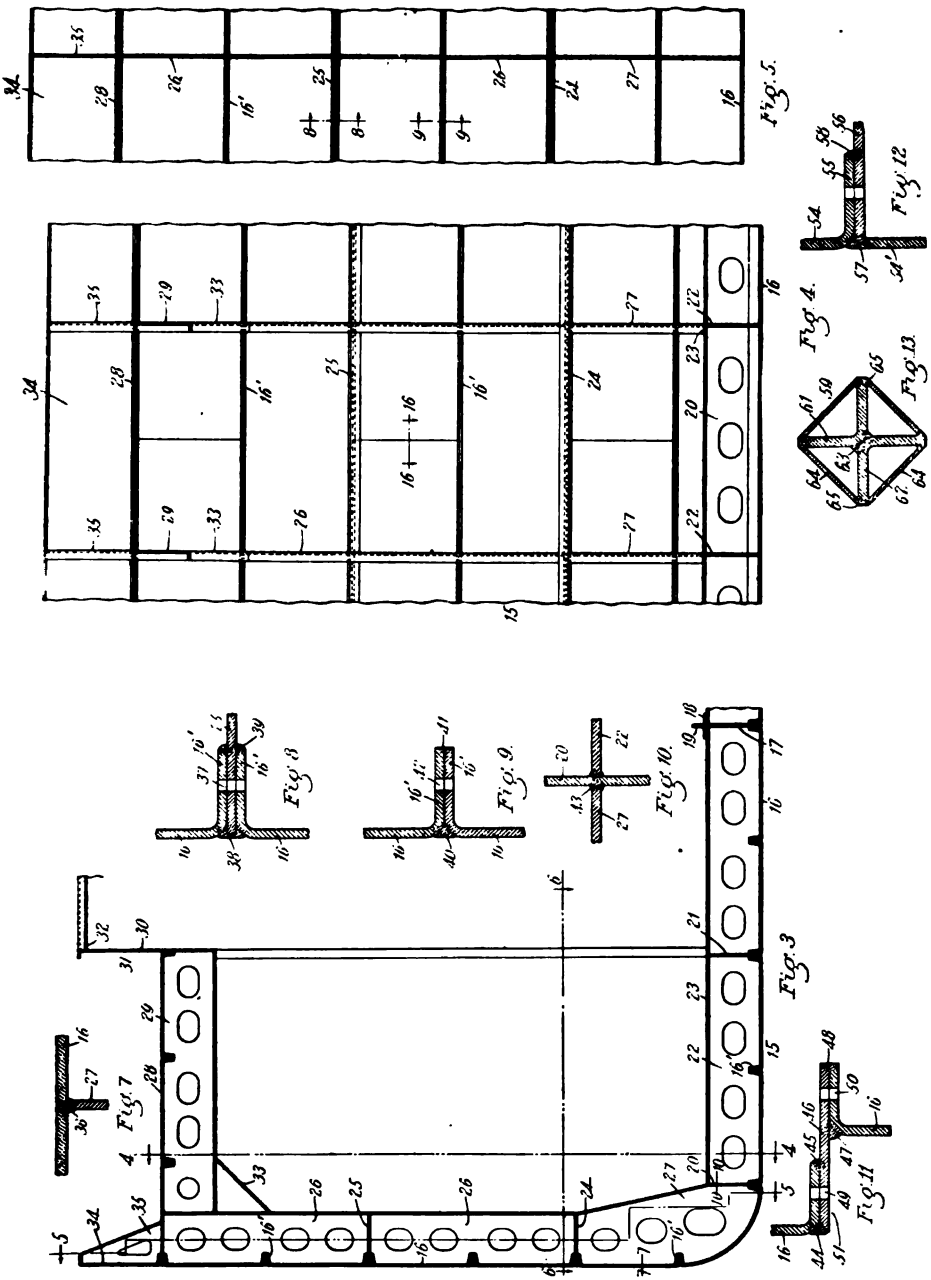
Fig. 2.



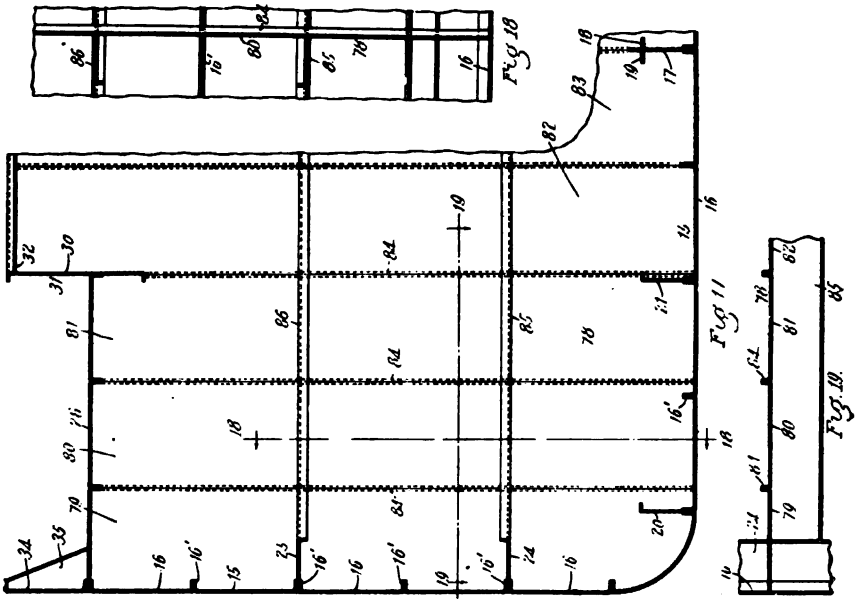


Fig. 10

Fig. 11

Fig. 12.

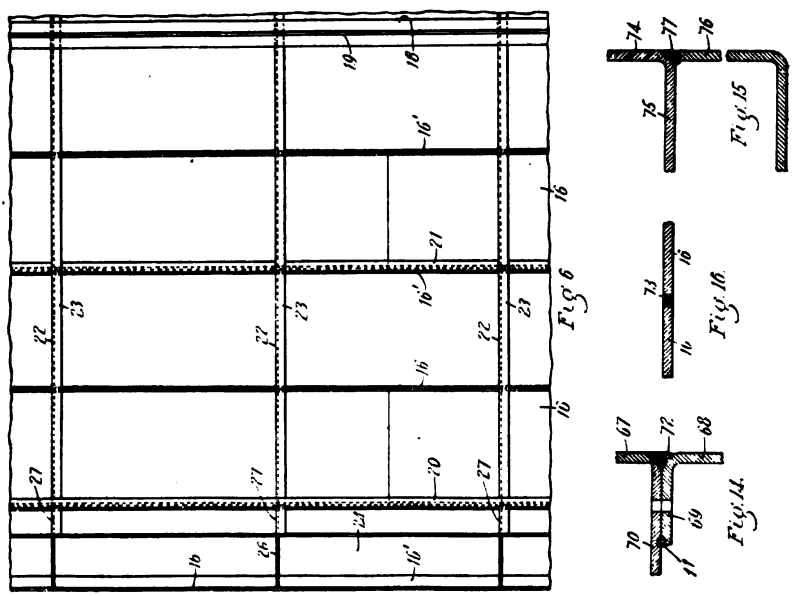


Fig. 6

Fig. 15

Fig. 16.

Fig. 14.

Report No. 6

COLEMAN CASTWELD PROCESS FOR SEAMLESS STEEL SHIP CONSTRUCTION.

The Coleman Castweld Process proposed for the construction of Seamless Steel Ships has been brought to my notice by Mr. Edward M. Carroll of New York.

A description of this proposition which has been invented by Mr. Clyde J. Coleman is included in this report. It will be noted that welding by means of oxy-acetylene gases is suggested for the uniting of cast metal sections, but bearing in mind the massive proportions of the parts to be welded, the substitution of electric arc welding is recommended for this purpose, as otherwise I do not believe the principle would be worthy of consideration.

DESCRIPTION OF "CASTWELD" PROCESS.

The invention relates to a new method and process for constructing and fabricating, resulting in a ship structure with its hull, ribs, beams, compartment, etc., all being integrated together, thus securing a lighter, stronger and more rigid ship unit, which will possess greater durability and safety in service than a ship fabricated from the present numerous plate sections, riveted together. Such a structure has more inherent weaknesses, especially at the seams, which are constantly liable to loosen, spring leaks and even pull apart by the shearing of rivets through the rolling, lurching, twisting, torsioning, etc., by virtue of the constant shifting of the mean center of buoyancy in a rough sea.

Such plate constructions also have very much greater resistance on account of the overlap at the seams, placing one or the other of the plate edge on end to the direction of travel, while on the other hand a ship built by my method and process will possess a hull exterior perfectly smooth and uniform, besides which it will be very much more able to withstand the buckling and collapsing pressure occasioned by its travel through the water. Furthermore, the time and expense necessary for the carrying out of my process as well as the time and expense for constructing the ship itself by this method and

process, are all so very much less than that by the present methods that it constitutes not only a very great advance in the art of shipbuilding, but otherwise a very great advance in the value to the world of marine commerce, whereby its urgent needs may be so very much more speedily fulfilled. Moreover, the rolling mill operation is by this process entirely dispensed with, thus effecting another great saving in time and expense by eliminating the need of extensive detailed blue prints and the delay and cost of securing structured steel from the rolling mills, before the construction or fabrication of the boat may be commenced. Instead of these delays and additional first cost, we only require the cost and time necessary for purchasing pig iron or ingot, which are substantially raw materials.

In its broadest sense the invention comprehends the coordination of the physics of casting and welding operations, so that molar masses may be autogenously put into structural forms. In other words, by such an integrating process, we secure a ship which is in its finished state all of one piece.

In the drawings which accompany this report.*

Fig. 1 is a plan view of the apparatus employed.

Fig. 2 is a sectional elevation.

Fig. 3 shows the heating jets.

Fig. 4 is a section thereof.

Figs. 5 and 6 show details.

The drawings show a ship hull 6 partly finished in plan section and elevation with the apparatus more or less diagrammatically represented for constructing such ship by the above-mentioned method and process. It will be seen that as the work progresses in the work of building up the ship in elevation that bricks 7 or other refractory bodies or materials are employed in building up the inside of the hull mould or matrix and bricks 8 to build up the outside. The upper layers 9 of such refractory walls are kept a certain number of inches above the upper hull and edges of the boat structure, and such elevated walls have their inner faces 10 surfaced with a refractory luting or cement 11 so as to seal the seams between the bricks or other wall forming bodies and thus provide a smooth and correct channel, mould or matrix for further building up by casting and fusing additional metal to the free edges 12 in continuation of the formation of the boat construction.

A narrow gauge trackway 13 is located around the entire hull of the vessel and trackways 14 across such hull at points where it is desired to construct bulkheads or compartment walls. These transverse trackways are associated with an overhead longitudinally arranged track 15 for conveying the ladles 16 with their attached trucks 17 which are used on the transverse narrow gauge trackways.

These trackways are for transporting portable ladles

*Not Printed in this Edition

which are filled with molten steel and are by this means moved along in such relation to the steel hull that the molten metal is allowed to flow in a properly controlled stream between the mould walls, and upon the exposed upper edge 12 of the structure so that such layers of steel will be fused to the previously built body forming the ship hull 6. In practice, it is preferable to employ a furnace for melting pig iron and then putting this iron through a converter, and reducing it to steel, and pouring from this converter into ladles which are raised by means of an elevator 18 to whatever working level the boat has been built up to, and removing the ladles filled with molten steel on to the trackways 13 whereby they are transported along the hull as above described. The drawings also show a supply of oxygen and a supply of acetylene and respective pipe lines 19 for each gas supply, such pipe lines being extended by means of an inverted U 20 over the trackways 13, and in turn connecting with distributing supply pipes 21, which extend all the way round the inner hull lines of the boat, and likewise the pipes 22 along the transverse compartment walls but opposite to that of the trackways. Branch pipes 23 are attached to both of these supply pipes at frequent intervals so as to supply a great number of oxyacetylene fusing and welding jets 34, which are also operated with an excess of acetylene so that such flames or jets will have a metallurgically reducing characteristic—in other words, to prevent the formation of any oxide films on the upper edge of ship structure upon which these jets are kept directed, to constantly keep this free edge at a fusion temperature, so that any metal streams which are supplied from the ladles will immediately be welded and united to the upper hull edge and likewise molded to form by the refractory mould walls.

The discharge spouts 25 of the ladles are to be so arranged that their discharge orifices discharge and project a solid stream of steel rearwardly and directly on to the free edge of the boat hull. This will insure a solid stream or mass of the molten metal being applied in the most efficient manner and will therefore effect a good union or weld with the upper free edge of the hull (which is kept at a welding temperature by the heating jets) and will thus permit of building up the superimposed layers in the most firm and solid manner. Another advantage obtained will be that the molten metal discharged in this direction will also greatly assist building up to the proper level, or in other words preventing the flowing down below the built up level of this added strata because the stream of fresh material is constantly being applied ahead of that which has just previously been applied. This action is, of course, also aided by the force of the fusion jets being all directed rearwardly in relation to the direction of travel of the ladles. Discharging these molten streams rearwardly also

prevents the same being broken up by impact against the mould walls as would be the case if they were discharged directly into the mould channels at right angles.

The ladle spouts are mounted on a guide 27 transversely arranged, relatively to the trackways, so that when the ladles have traveled along the hull and the discharge spouts are opposite a rib member 29, the movement of the ladle truck is arrested and the discharge spout given a to-and-fro transverse movement by its operating lever 28, so that the stream of molten steel will be applied to the building up of the rib members.

An overhead crane 26 running on tracks 15 may be employed to transfer the ladles of molten metal to the work.

It may be found necessary to dilute the oxygen supply with a certain amount of air and also to dilute the acetylene supply with a lower grade of hydro-carbon gas or even to substitute a gas of a lower heating value than the acetylene, because otherwise the oxyacetylene flame may have too high a critical temperature, whereby the surfaces of metal would be boiled and vissicated, which would greatly impair the tensile strength of the union or welds between the various superimposed layers.

Report No. 7

APPLICATIONS OF ELECTRIC ARC WELDING TO SHIP CONSTRUCTION, DEVELOPED BY MR. W. T. BONNER, OF OF CHESTER SHIPBUILDING CO.

A. DESCRIPTION OF WORK.
B. RESULTS OF WELDING TESTS.

SECTION A: DESCRIPTION OF WORK

(1) Mr. W. T. Bonner has contributed the attached photographs of certain most interesting electric welding work which has been executed within the last two years. In addition to these illustrations Mr. Bonner has referred me to earlier pioneer work, including the manufacture of cylinders out of 6″ diameter tube with welded malleable iron ends, as evidence of the superiority of welding over riveting to obtain pressure tightness. It is stated that the average time required to weld a 6″ dia. circ. seam (i. e. 18″ peripheral length) was 11 minutes and with all standby losses added, the working average was 4 finished ends per hour.

(2) The most important electric welding undertaking carried out by Mr. Bonner was a portion of a 1,200-ton Bulk Oil Barge designed for service in Mexico.

This is shown in different stages of completion.

Dimensions were as follows:

Length B. P. 165′ 3″
Breadth moulded 37′ 9″
Depth 8′ 6½″

(A) The shell and deck plating was of ¼″ whilst the transverse framing members, intercostals and the like, were all of $\frac{5}{16}$″ plating. After completing the 60 feet 'midship section by welding, the remainder of the barge was given over for finishing the construction by riveting in order to compare maintenance costs of the two types.

Because of the badly twisted and buckled condition of the plating and framing supplied for this job, the work of assem-

Electric Arc Welded Cylinders (See Page 107).

bling was considerably multiplied. Some idea of this may be obtained from photo of keel plates as laid April 19, 1917. The two views of keel plating and channel longitudinals, as on April 22nd, show how completely the buckled condition was eliminated and, by reference to the port side views of finished bulkheads, it will be noted that all framing and plating was brought up true and square. In short, the following may be regarded as the accomplishments which Mr. Bonner's experience has demonstrated may be duplicated with certainty on future work.

1st. Straight work may be made out of very badly bent and twisted plates and channels.

2nd. Thin plates of large area may be welded without a warp or buckle.

3rd. Tight joints, metal solid against metal, may be made without punching a single hole for holding bolts.

4th. Work was absolutely square and true as shown by steel straight edge.

5th. Feature No. 3 was accomplished with less than one-fourth the expenditure of time and material required for previous methods of assembling work.

The accompanying tables are appended to show the relative cost of riveted and welded barges, one column of figures representing the former as developed during the construction of three barges and the latter by estimating the total from actual costs of work on the section illustrated. The section of bilge plating and framing defined by white lines on photos No. 7 and 11 has its exact counterpart in photos No. 8, 9 and 10 designed by Mr. Bonner to illustrate a typical rivetless ship. The following table shows, by actual measurement and count, the absolute superiority of welded over riveted construction for ships. It is estimated by Mr. Bonner that the lesser weight of material in the welded type would enable five ships to be built with the steel now required for four.

It is claimed that this work when completed demonstrated the advantages of electric welding to obtain rigidity of structure, low frictional resistance, ample bracing, smooth interior and exterior surfaces and freedom from corrosive tendencies.

Photo print No. 12 is a deck view looking aft, on the S. S. "Hisco" as she was nearing completion. Close inspection of this picture reveals a large amount of electric welding, including amongst other details the fixing of the crows nest to the mast without studs or rivets either for permanent or temporary use.

The two views of a typical section of outside plating transverse and longitudinal framing, shown in photograph No. 13, is appended to illustrate the application of electric welding to ships and barges constructed on the Isherwood principle. The section shown in this photograph was constructed entirely

1

A First laying of Keel Plate for Electrically Welded Barge.

Note—Badly buckled condition of Plate edges. Latter were all drawn up perfectly straight for weld without use of bolting holes.

2

B All Riveted Barge of similar size and type, ready for launching.

Note—The same ways were afterwards used for construction of Welded Barge of same type.

3

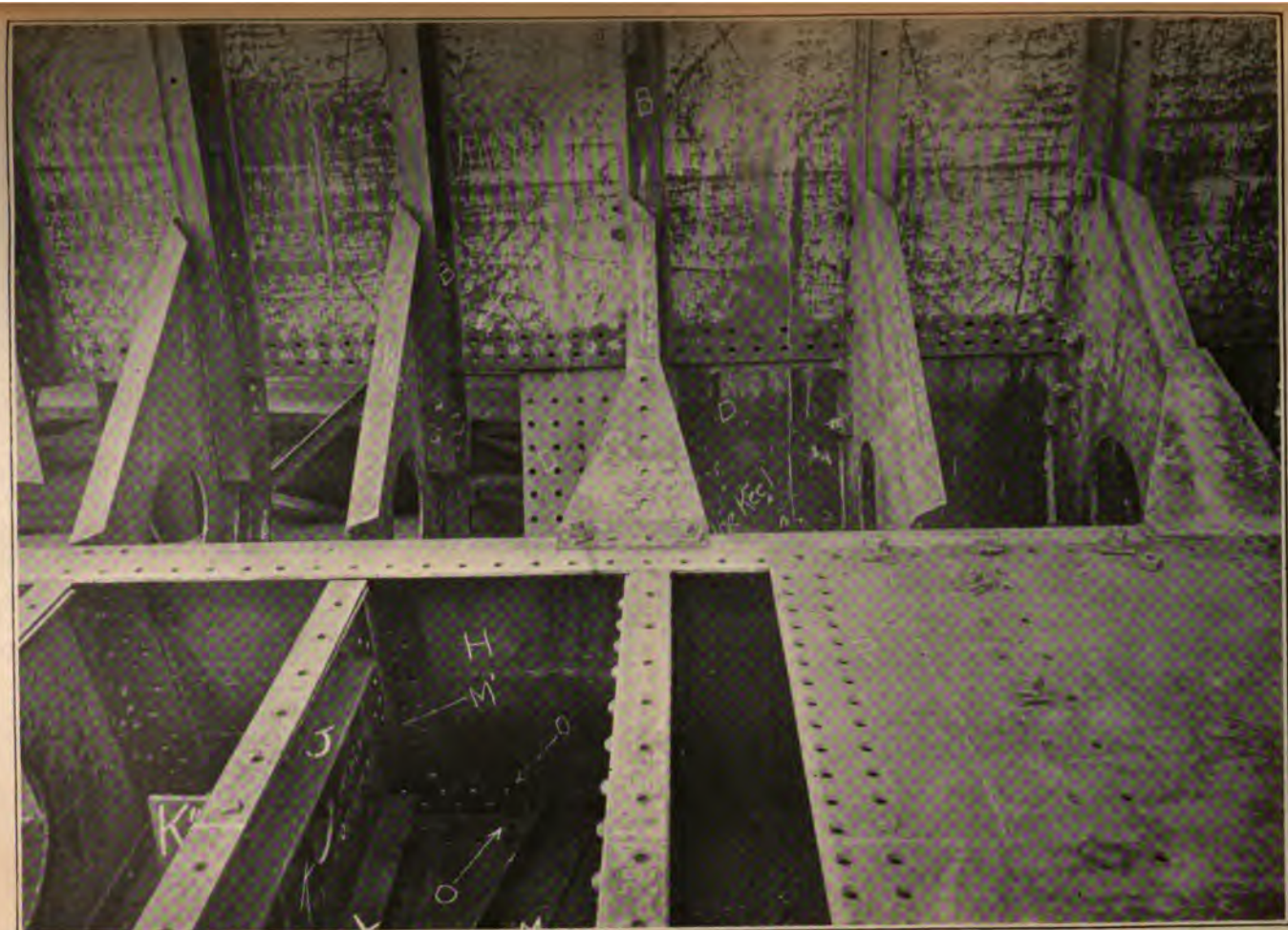
Top View of Keel Plating with first longitudinal framing members and bottom support for center line bulkhead "tacked" in place. Note—How plate edges have been straightened.

4

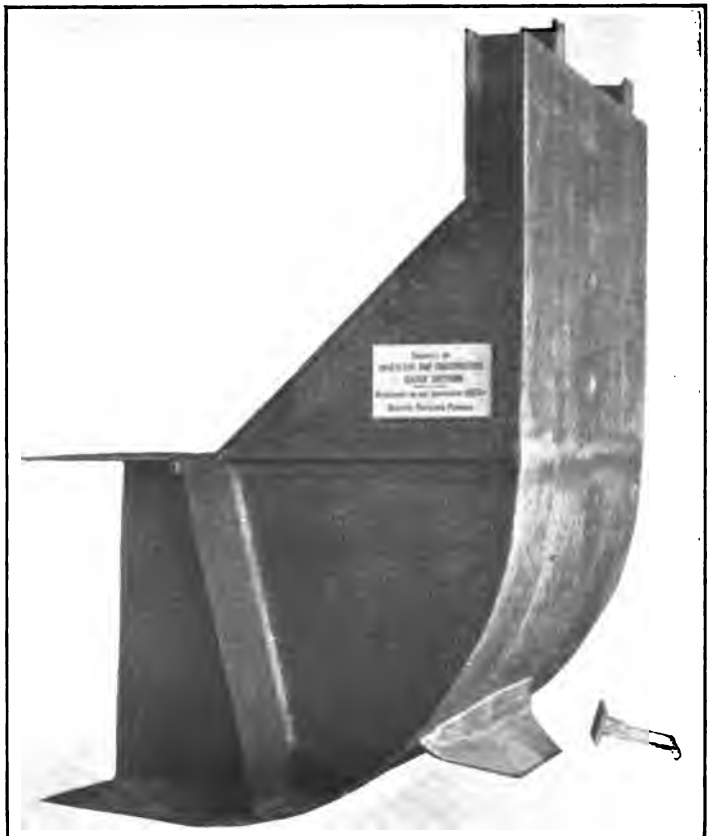
Side View of above.

5
View showing finished connection between centre line bulkhead and underside of deck plating with inboard section of transverse frame.

6
View looking aft along port side of centre line bulkhead and showing longitudinal B. H. Stiffeners and bottom longitudinal with inboard portion of transverse frames.



7 Portion of Bilge of 7800 ton Cargo Ship defined by white lines shown for comparison with all Welded Section of same size and shape as illustrated by Photos. 8, 9 and 10.



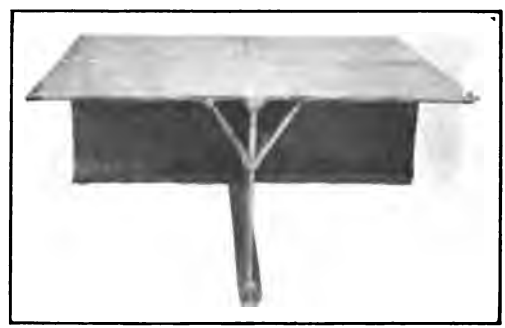
8
Rivetless Section of Bilge Portion of Cargo Ship.
Designed by Wm. T. Bonner, Engineer Welded Ship construction
Philadelphia and Chester

9
Quarter View of Bilge Section of Rivetless Cargo Ship.

10
Interior View of Bilge of an all Welded Ship Section, full size for 7800 tons.

11. Another View of Blge Section of Standard Riveted Cargo Ship. See Photos 8, 9 and 10 for duplicate of this section reproduced as an all Welded Structure.

12 Deck View of S S Hisco nearing completion at Chester Ship Yard as on Dec. 4th, 1917. **Crow's Nest Welded to Mast** under direction of Wm. T. Bonner, Engineer Welded Ship Construction.
Note –This is understood to be the first Ship to leave any port with Electrically Welded Crow's Nest.



13

Two Views of a Typical Section of Outside Plating Transverse and Longitudinal Framing

14
Typical Deck Rail Stanchions.
Bonner Welded Type.

of plating for all members excepting the inclined braces of common merchant bar stock and the bulb portion of framing which was formed by welding two half round bars along the edges of plates.

A new type of deck rail stanchion is shown in figure 14 for standardized ships being constructed at the Chester Yard. This is formed by welding a plate base to bottom end of a 3" I beam. The top end is finished by welding a curved plate corresponding in width and thickness to the beam flanges or by closing over projecting ends of flanges to a butt weld in center. The web beam is punched for admission of rail rods which may be "tacked" to stanchion when assembled in place.

COMPARATIVE DETAILS OF RIVETED AND RIVETLESS SHIP STRUCTURES DEVELOPED BY MEASUREMENTS OF ACTUAL BILGE SECTIONS ILLUSTRATED BY APPENDED PHOTOGRAPHS.

Ref.	Particulars	Riveted	Welded
A	Weight of Plates required.....	2488 lbs.	1884 lbs.
B	Weight of Angles, Beams and Channels	764 "	194 "
C	Weight of Straight Bars.....	none	360 "
D	No. of 5/8" Rivets.....	48	none
E	No. of 3/4" Rivets.....	231	"
F	No. of 7/8" Rivets.....	108	"
G	Total No. of Rivets.....	387	"
H	Total Weight of Rivets.....	200 lbs.	"
I	No. of Liners required.....	4	"
J	Weight of Liners.....	31 lbs.	"
K	Weight of Weld material added....	none	120 lbs.
L	Total weight of complete section...	3483 lbs.	2558 "
M	Lineal Feet of Heavy Flanging and Shaping	22	none
N	Sq. ft. of Forge Shaped Bilge Plate.	24	"
O	Sq. ft. of Machine Rolled Bilge Plate	none	20
P	No. Lineal feet of welds in terms of 1/4 sq. in. Section.....	"	620
Q	No. Lineal feet of Caulked Edges...	57	none
R	Total No. of all Rivet Holes in Section	826	"
S	Average Area of Plates of full size..	17280 sq.in.	15235 sq.in.
T	Average No. of Rivet Holes in same	550	none

U	Average Area of Rivet Holes in same	432 sq. in.	
V	Reduction of Plate Area due to Punching	2½%	"
W	Typical No. of holes in Rows across Plate	15	"
X	Average Total Diameter of Rows across Plate	15%	"
Y	Average Proportion of Hole Diam. to Plate	25%	"

Notes:—

Above includes no allowance for Bilge Keel.

All plates are calculated as of same thickness for both types.

ESTIMATED CONSTRUCTION COST OF 166'x39'x8'8" BARGE

Items	Riveted Design	Welded Type
Plate Fitters	$1,236.00	$618.00
Punching and Shearing	1,045.00	522.00
Countersinking and Reaming	976.00	
Riveting	3,427.00	
Chipping and Caulking	523.00	265.00
Smithwork	557.00	275.00
Assembling	2,010.00	1,320.00
Electric Power	382.00*	95.00*
Foreman	360.00	360.00
Plant		300.00
Superintendence		900.00
Rivets	780.00	
Liners	142.00	
Shed and Shoring Lumber		145.00
Welding—Assembling & Construction		
51,300 ft. Single Fillet—		
Welders—6,000 hrs. @ 60c...$3,600		
Current—6,000 x 5 30,000 K.W. H. @ 2½c.... 750		
Wire—7,200 lbs. @ 6½c..... 450		
		4,800.00
Incidentals		250.00
Profit		1,000.00
Total	$11,438.00	$10,850.00

*Current used for Lighting, Punching, Shearing and Air Compressors only.

**All figures for Riveted Design based on Actual Book Cost of 3 barges.

Editor's Note:—Mr. Bonner has since supplemented the above with the following statement:

"When completed the barge was loaded with 500 tons of fire brick, pipe, lumber, cement, etc., and towed 60 miles to New York, where it also took on about 500 tons of pumping machinery. With this near capacity cargo the barge started on an ocean voyage of 2500 miles around the Capes to Tampico, where it arrived in due course with hull and cargo in good condition.

"No repairs have thus far been required, notwithstanding the barge has been in service about twelve months as a bulk oil carrier on the Panuco River, where the rapid current, wind and tides combine to make navigation difficult."

SECTION B.

RESULTS OF WELDING TESTS.

TABULATED RESULTS OF WELDING TESTS.

Mr. Bonner has very kindly supplied me with tabulated results of tests carried out under his direction at the United States Bureau of Standards, Washington, during January and February, 1917. These results are most interesting as they cover a wide range of applications with different forms of joints welded with the oxyacetylene and electric arc systems.

I understand they were primarily carried out with a view to determining the relative efficiency of various types of joints for shipplating (see insert).

Report No. 8

Mr. E. B. Katte's Investigations Relating to Arc Welding.

A—CONFIDENTIAL REPORT.
B—DESCRIPTION AND RECORD OF TESTS.
C—SPECIFICATION OF WELDING APPARATUS.
D—SPECIFIED METHOD OF MAKING TESTS.
E—APPENDIX.
F—RECORD OF TEST WITH QUASI AND OTHER ELECTRODES WITH ALTERNATING CURRENT.

SECTIONS A TO E.

Confidential Report
(Not Printed in This Edition.)

SECTION F.

RECORD OF TESTS WITH QUASI AND OTHER ELECTRODES WITH ALTERNATING CURRENT.

Section F—Bending and Torsion Tests of Welds made with Quasi Arc and other electrodes with alternating current welding machine at West Albany Shops, week of January 4 to January 11, 1918.

Test piece No.	Welder	How Welded	Degrees Bend	Degrees Twist	Remarks
PQ 1	Knapp	Flat in layers	—	—	Broke o. s. weld
" 2	"	"	200	—	twice, i. e. second grip taken
" 3	"	"	—	—	No piece twisted
AQ 2	"	Down in layers	—	540	
" 3	"	"	200	—	—
" 4	"	"	—	—	—
BQ 1	"	"	—	500	Plate when fin-
" 2	"	"	200	—	ished was bent
" 3	"	—	—	—	up angle 10°
CQ 2	Gilleran	Vertical	60	—	—
" 3	"	"	—	270	—
" 4	"	"	—	—	—
DQ 1	"	"	—	225	—
" 2	"	"	60	—	—
" 3	"	"	—	—	—
EQ 2	Knapp	Down in layers	100	—	—
" 3	"	"	—	—	—
" 4	"	"	—	—	—
FW1	Gilleran	Vertical	45	—	—
" 2	"	"	—	—	—
" 3	"	"	—	—	—
" 4	"	"	—	225	—
GH 1	"	Vertical	—	300	—
" 2	"	"	—	—	—
" 3	"	"	—	—	—
" 4	"	"	60	—	—

4 test pieces of original steel pulled—average 60,000 lbs. per sq. in.

Tensile tests of welds made with Quasi Arc and other electrodes with alternating current welding machine at West Albany Shops, week of January 4 to January 11, 1918.

Test Pc No.	Wire Used	Voltage	Current	KWH per lb. of metal	Width of Strip	Thickness of Strip	Area of Strip	Pounds Pulled	Pounds per sq. in.	Metallic Fracture	Elongation	Fracture
PQ 1		30	70	2.25	1.99	.39	.78	47000	60500	100%	22%	outside of weld
" 2	No. 100A British	30	70	2.25	2.0	.4	.8	46190 49000 47000	59000 61000 59000	100%	20%	outside of weld
" 3		30	70	2.25	2.	.4	.8	—	--	—	—	—
AQ 2		30	90	2.3	2.0	.4	.8	—	—	—	—	—
" 3	No. 10 QA	30	90	2.3	2.0	.4	.8	43360	54000	93%	15%	in weld
" 4	Regular	30	90	2.3	2.	.4	.8	—	—	—	—	—
BQ 1	"	30	110	2.2	2.	.4	.8	—	—	—	—	—
" 2	"	30	110	2.2	2.	.4	.8	—	—	—	—	—
" 3	"	30	110	2.2	2.01	.4	.8	41550	51000	90%	15%	in weld
CQ 2	"	30	80	—	2.	.4	.8	—	—	—	—	—
" 3	"	30	80	—	2.	.4	.8	—	—	—	—	—
" 4	"	30	80	—	2.02	.42	.846	39680	47000	100%	10%	½ crystal ½ silky
DQ 1	"	30	80	—	2.	.4	.8	—	—	—	—	—
" 2	"	30	80	—	2.	.4	.8	—	—	—	—	—
" 3	"	30	80	—	2.03	.4	.812	34110	42000	96%	10%	fine crystal
EQ 2		30	110	2.2	2.	.4	.8	—	—	—	—	—
" 3	No. 6 QA	30	110	2.2	2.	.42	.84	43840	52000	96%	10%	crystalline
" 4	Regular	30	110	2.2	2.06	.417	.86	43810	52000	98%	10%	"
FW 1		15	140	2.22	2.	.4	.8	—	—	—	—	—
" 2	5/32	15	140	2.22	2.07	.37	.765	39170	51000	100%	6%	crystalline
" 3	bare	15	140	2.22	2.01	.36	.723	34550	49000	90%	6%	"
" 4	wire	15	140	2.22	2.	.4	.8	—	—	—	—	—
GH 1		15	120	—	2.	.8	.8	—	—	—	—	—
" 2	1/8	15	120	—	2.1	.4	.84	33570	40000	90%	8%	crystalline
" 3	bare	15	120	—	2.06	.38	.78	36160	47000	100%	8%	"
" 4	wire	15	120	—	2.	.4	—	—	—	—	—	—

Report No. 9

Title: New York Shipbuilding Company's Investigations Relating to Spot Welding.

A. Description and Remarks.
B.—Photographs and Tabulated Test Results.
C.—Report of Water-Tight Bulkhead Door.

SECTION A—DESCRIPTION AND REMARKS

The following report was made by Mr. James Young, of the New York Shipbuilding Company:

Due to the great necessity of speeding up work on the torpedo boat destroyers and merchant ships building at this yard, it occurred to me that electric spot-welding of certain parts of their structure might be practicable and be the means of a great saving in time, but having no experience or data on this subject, I set about making tests, the results of which will be stated later.

Electric arc welding is now being used to some extent in some yards, in the construction of ships, as well as in repair work, but it does not appear to me to be as suitable for ship work as electric spot-welding, which in appearance is practically the same as flush riveting and is quicker and less expensive than arc welding.

As far as I understand, electric spot-welding was first put into practical use about fourteen years ago, but it was not until October, 1916, that one of these welders was installed at this plant.

For some time back we have specified electric spot-welding to take the place of riveting on light sheet iron work of all descriptions, up to about No. 10 B. W. G. in thickness and this construction has proved extremely satisfactory.

It was only a matter of proceeding further with its use and applying it to thicker material and at the same time investigating if electric spot-welded joints can be made equally as strong as the various types of riveted joints used in ship construction.

It was also desired to go a step further and find out if these spot-welded joints could be made water-tight without having to be caulked, as in the case of riveted joints.

Accordingly, a number of experiments were made to obtain a watertight joint by the use of various kinds of fluxes, some of which appear to make the joint perfectly watertight, and it is expected that tests will be made, in the near future, to prove the efficiency of this additional feature in connection with spot-welding.

Early in October, 1917, we started to make a few tests on electric spot welding of steel plates one-eighth inch thick and up to three-quarters inch thick, but did not start to keep any

records of these tests until the middle of the following month.

The electric spot-welder used, being the only one installed in this yard at the present time, is located in the tin shop, and is a "National" of 220 volts, 25 amperes, which is reduced to probably 4 volts and 80 amperes on the No. 8 point of the machine.

It was soon found that, due to the small power of the machine, it was not advisable to use it on plates over three-eighths thick, this thickness being the limit of its capacity; the plates tested, therefore, were generally three-eighths inch in thickness and under, as shown on the test reports. There appears to be no doubt whatever but that with more powerful welders, plates of any usual thickness used in shipbuilding could be connected in this manner, with equally satisfactory results as the thinner plates tested.

It is also believed and suggested that any of the present gap riveters now in use in the plate and angle shop could easily be converted into electric spot-welders by being fitted with transformers, etc., and still retain the compressed air feature to press the parts together while spot-welding.

Some trouble has been experienced in keeping the electrodes cool by the circulation of water, as at present arranged on the spot-welder, and it is believed that a further use of the compressed air supplied to the converted machines could be made with advantage, to keep the electrodes cool and be more efficient than water circulation, but this would have to be tried out to prove which system was the most efficient.

Various types of electrodes were tried out, including the roller type, but we appear to get the best results with the flat type now being used, which are 1¼" diameter, with a ¾" diameter contact surface.

It is probable that the best results may be obtained by varying the diameter of the contact surface to suit the thickness of the material to be welded.

It does not appear advisable at this time to propose the use of spot-welding on the shell or deck plating of vessels, as this might introduce complications, but there appears to be no doubt but that it can be applied to all parts of a vessel's structure, which are now riveted together in the shops.

The test sheets and accompanying photographs of pieces tested are, no doubt, self-explanatory, but in examining the results it should be kept in mind that the current supplied to the machine varied to a very great extent, as it is on the same line which supplies current to other shops. It would seem advisable that electric spot-welders should be on a circuit by themselves.

The tests referred to in this report were made under more or less adverse circumstances, and it was necessary to go about the matter slowly in order to get the proper people interested.

Considerably more progress could have been made if we had built a tank fitted with watertight door, and had it tested, in order to prove the practicability of spot-welding in structural parts of a vessel. We have now submitted a sample spot-welded manhole cover to the Bureau for the destroyers building here, and have requested the Bureau's approval of the use of spot-welding on all manhole and hatch covers, doors, etc., and on all work of this kind for all of these vessels, and it is fully expected that approval will be given.

It appears advisable that no time should be lost in building a tank for test purposes, so that we might propose the use of spot-welding on the various structural parts of a vessel. Only certain parts of this tank could be spot-welded with the present facilities at our disposal, but this should be sufficient to prove the efficiency of spot-welding.

The following are a few of the advantages claimed for electric spot-welding:

(1) There is considerably less work involved in the development of plans, as a general note would cover all the information necessary regarding spot-welding.
(2) Elaborate templates are not necessary for this kind of work.
(3) Laying out of the holes and centerpunching same are eliminated.
(4) Punching of holes (sometimes reaming or drilling), countersinking and riveting are eliminated.
(5) The closer spacing of the spot-welds than that of rivets does not weaken the plates as would rivet holes and permits of better caulking and insures perfect watertight work where required.
(6) The necessity for accuracy in matching holes is eliminated.
(7) The above enumerated operations necessitate a considerable amount of handling, which is reduced to a minimum by spot-welding.
(8) Many of the tools used in these operations might be dispensed with.
(9) The men can be taught how to use the welder in a short space of time.
(10) It is probable that by using a flux, as stated elsewhere in this report, caulking the edges of plates or bars, including the bevel planing of same, may also be eliminated.

All the templating that would be required, as regards rivet holes, would be to locate a few anchor or pilot holes, as may be found necessary to insure that the various parts fit together properly in their relative positions.

James Young.

SECTION B

PHOTOGRAPHS AND TABULATED TEST RESULTS

(Not Printed in This Edition.)

SECTION C

REPORT OF WATERTIGHT BULKHEAD DOOR

Test Made

at New York Shipbuilding Corporation yard, 3 P. M., Tuesday, April 2d, 1918. Electric spot-welding was completed on Thursday, P. M., March 28, 1918, under the supervision of Messrs. James Young and William G. Schrader. Arc welding in place of caulking was completed on Monday, A. M., April 1st, 1918, under same supervision.

The spot welder used was not adequate for the work undertaken, and the results that follow must be so interpreted.

Description of Door:

Overall size of door was 2′—5½″ x 5′—9″ (see plan "A" Sheet "A-1").

Plate was ¼ inch thick and weighed 10 pounds per square foot. A 3 inch x 3 inch x $\frac{5}{16}$ inch thick angle was used for the frame and was fastened to the plate with 141 spot welds, approximately 1⅜ inches on center along outer edge and 39 auxiliary welds near heel of angle about 6 inches on center. The 141 welds were used in an endeavor to melt a flux into the seam in place of caulking, but this was found unsatisfactory with the present equipment. Relative to strength of welds these 141 could be reduced to 65 welds about 3 inches on center with 18 auxiliary welds at heel of angle about 12″ on center, the edges being arc welded instead of being caulked.

Angle stiffeners were 3 inches x 2½ inches x $\frac{5}{16}$ inch thick and were fastened to the door plate with 8 spot welds on the 3 inch leg. Owing to the vast deflection of plate at time of applying the stiffeners it was necessary to use 10 welds on each of stiffeners No. 1 and No. 2

Sheet A-2. Watertight Bulkhead Door.

(Sht. "A-1"), but of these 10 welds only 8 welds eventually took proper hold. The other two welds were merely to tack the stiffeners in place temporarily, owing to the extreme warping of plate and unsatisfactory clamping arrangement. By allowing 10 welds to each stiffener, however, the connection would be considerably stronger.

Welding Time:

Owing to lack of proper equipment, the actual time consumed on this particular operation cannot be taken as a standard of estimate. The following paragraph headed "Possible Time for All Welding" will be found an approximate estimating time under favorable working conditions. Also this work under proper conditions could be done by one operator only.

Possible Time for All Welding:

Clamping door and frame (8 clamps @ 3 min.)	24 min.
Changing electrodes (1 time @ 15 min.)	15 "
Clamping stiffeners (6 clamps @ 3 min.)	18 "
83 welds @ 10 seconds	14 "
30 welds @ 10 seconds	5 "
Time between welds (113 @ 10 sec.)	19 "
Arc welding, 196 inches @ 5 inches per min.	39 "
Removing clamps (14 @ 2 min.)	28 "
Allowable lost time and extra work, 10%	17 "
Total time required for one man	2 hrs. 59 min.

Test:

The door was laid flat on a steel plate ⅜" thick and held in place with clamps approximately located to correspond with the dogs of actual fittings. (Plan B, Sht. A-1.)

The clamps were fastened with 1" diameter bolts through the steel table top (Sect. E, Sht. A-1).

A 1⅞" thick block was laid at each end of door and a straight-edge laid across these blocks for obtaining the deflections (Plan B, Sht. A-1).

Before any water was let into door, the deflections were as shown on Sect. B, Sht. A-1.

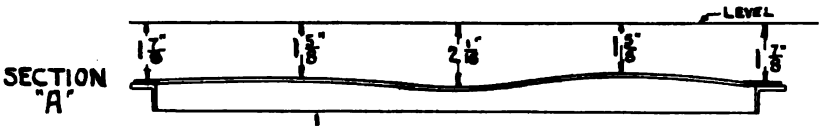
With the water at a pressure of 5 pounds per square inch, there was no deflection noticeable nor were the least signs of leakage visible.

With the water at a pressure of 10 pounds per square inch, a slight deflection occurred on the top end and at the center (Plan A, Sht. A-1), as indicated at Sect. C, Sht. A-1, but no signs of leakage.

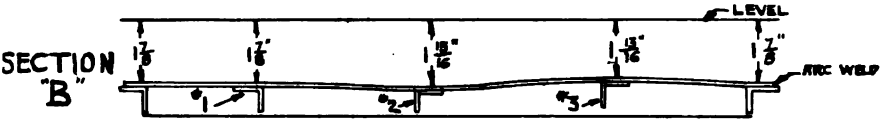
With the water at a pressure of 15 pounds per square

ILLUSTRATIONS OF W.T. DOOR TESTED AS PER REPORT A" ATTACHED

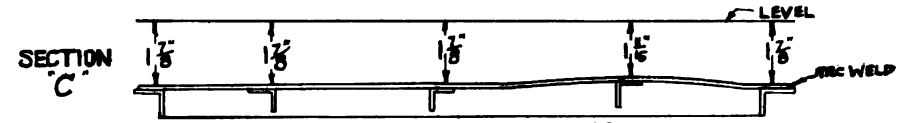
DOOR 10 POUND PLATING. TEST 20 LBS SQUARE INCH 46 FT. HEAD



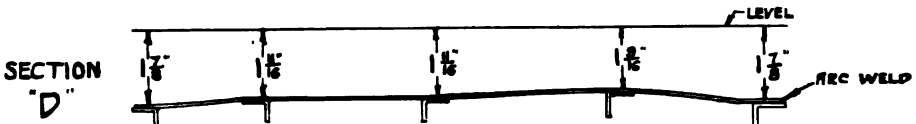
PLANE OF PLATE BEFORE & AFTER WELDING ANGLE FRAME



PLANE OF PLATE AFTER WELDING ANGLE STIFFENERS & BEFORE TEST



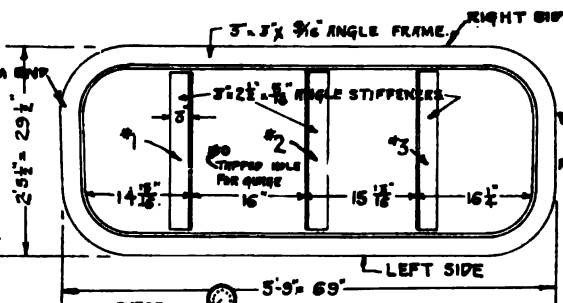
PLANE OF PLATE WITH INTERNAL PRESSURE OF 10 POUNDS PER SQUARE INCH

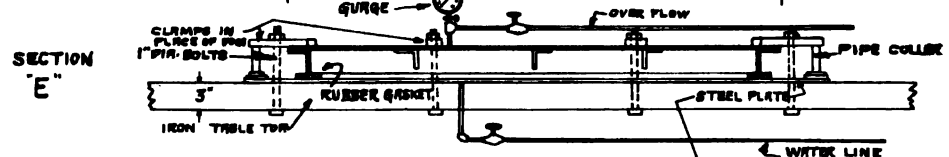


PLANE OF PLATE WITH INTERNAL PRESSURE OF 15 POUNDS PER SQUARE INCH

PLAN "A"

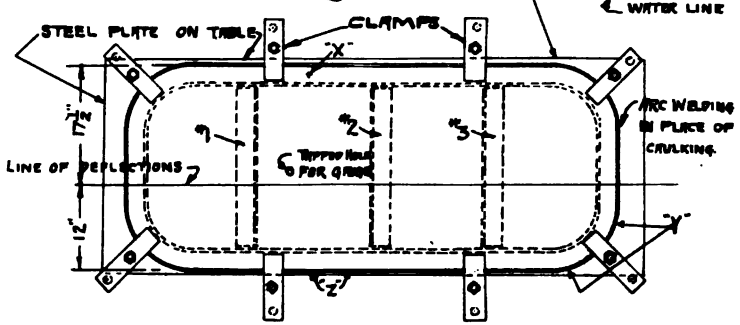
SHOWING UNDER SIDE OF TEST DOOR AND ARR'G'T. OF ANGLE STIFFENERS. EACH STIFFENER HELD IN PLACE WITH 8 SPOT WELDS.





PLAN "B"

SHOWING TOP OF DOOR & APPROX. POSITION OF CLAMPS.



Sheet A-1

inch, the deflections increased as indicated on Sect. D, Sht. A-1, but still no signs of leakage.

With the water at a pressure of 20 pounds per square inch, one of the welds on stiffener No. 3 broke loose, increasing the deflection somewhat, but no leakage appeared. However, when the pressure reached 22½ pounds per square inch, three distinct reports were heard, indicating that some further welds had pulled loose on the stiffeners.

It later developed, when door was removed from the testing table that on stiffener No. 1, seven welds had given away and that this stiffener was held in place by only one weld on the left-hand side.

The center stiffener No. 2 had broken away entirely from all welds, and stiffener No. 3 had broken away at only one (1) weld.

However, it should be noted that not one of the welds either at the stiffeners or at the frame showed the slightest signs of leakage, although one weld before the test showed a burnt hole. This weld, shown at "X", Plan B, Sht. A-1, was filled in with arc welding and after the test, no welds on the frame showed any signs of breaking away. In fact, the door could have showed a higher pressure if allowed, before any leak would have shown at the frame. This, however, was unnecessary, as the door under its test had withstood pressure far beyond the maximum requirements.

Before testing, the door was photographed in position on the testing table, and a copy of this photograph accompanies this report. (Sheet A-2.)

Report No. 10

HOLSLAG SYSTEM OF ARC WELDING

Mr. W. J. MURRAY, President Electric Arc Welding Company of Newark, has kindly forwarded to me particulars of a welding outfit suitable for operation with alternating current. This outfit was recently developed by Mr. Holslag, of the New York Central Railway Company.

I have made myself familiar with the action of this outfit which I have seen in successful use. There would appear to be a great future for such equipment for service with either bare or flux covered metal electrodes. The "Holslag" apparatus is referred to in the following description:

Welding from alternating current with the type of apparatus above referred to has certain advantages and disadvantages as compared to welding with direct current. These may be classed under the following headings:

1st, Heat Control; 2nd, Efficiency; 3rd, Portability; 4th, Power Supply; 5th, Wiring; 6th, Maintenance; 7th, Power Factor.

Heat Control:

The general effort in electric welding work is to maintain either a constant current or, preferably, a constant wattage at the arc. The constant current from the D. C. source can only be approximated and commonly involves the use of the series resistance, which consumes considerable energy within itself. By the use of reactance control, which consumes but little energy, a very stable regulation can be obtained with the A. C. welding equipments, with the result that practically a constant watt input is obtainable. The current reduces just enough with the lengthening of the arc to accomplish this. The amount of the watt input to the arc can, however, be adjusted to the work and the electrodes employed by means of an easily moved shunt in the magnetic circuit or by means of voltage taps from the plugging board.

Efficiency:

A well designed transformer is naturally an efficient piece of apparatus, as it has no moving parts, and, consequently, no friction and windage. The regulation does not materially

affect the efficiency, so that a much higher electrical efficiency can be obtained. This ultimately shows in the number of kilowatt-hours per pound of metal deposited. As all power costs money, the saving in having an electrically efficient device is obvious.

Portability:

Outside of the rare cases where welding can be done from a D. C., 110-volt circuit, the D. C. welding work requires a motor generator set of considerable size. In addition, there is a switchboard, so that the total weight may run up to from 1 to 2 tons. While these D. C. outfits may at times be put on wheels, yet they are too heavy, as a rule, to be moved except by means of a crane, so that portability in a strict sense is never possible with D. C. welding outfits. The A. C. set, even in the largest size, weighs only about 200 pounds and may, therefore, be carried around by two men without difficulty and set on or under a bench or anywhere convenient to the work.

Power Supply:

The general power distribution in this country is by alternating current, usually of 60 cycles. The A. C. welding equipment is therefore immediately adapted to the power supply without changing any of its characteristics, as is the case in the D. C. system. Further, the power can be brought to the welding outfit at any of the convenient distributing volts, such as 220, 440 or 550. The outfit can also be connected in whatever way is most satisfactory to the power supply, thus reducing any possible disturbances in their circuit. Machines can also be made which will take power from more than one phase, although that is not commonly recommended. In general, when more than one machine is in operation, they can be divided up among the various phases to reduce the possible disturbances in the circuit.

Wiring:

When the welding work is scattered, a D. C. system involves a low voltage, heavy current distribution with consequent expense for copper. The A. C. system permits the distribution to be made at a comparatively high voltage on low current with transformation to a high current and low voltage near the welding operation. The result is a much reduced expense for distribution copper, as well, of course, as the reduced expense for the outfit itself.

Maintenance:

The maintenance of any motor generator with a switchboard involves greater skill than that required for a transformer and the deterioration will be greater. The A. C. apparatus, having no moving parts except a small fan, should last indefinitely unless actually torn to pieces by some serious accident, such as having something drop on it. The electric fan now used will probably be replaced in the future by a more practical form of blower.

Power Factor:

The one disadvantage under which an A. C. welding system labors is the fact that its high efficiency is obtained by the use of reactive control, which, while it does not consume energy does consume power factor. Stable alternating current arc has a power factor of from 15 to 25 or 30 per cent. The objection to this is not serious when the amount of the power being used for welding is small compared to the capacity of the supply circuit. This makes the A. C. system particularly well adapted for isolated, single unit outfits for doing rapid work intermittently in various parts of the shop. When a large amount of welding is to be done in one location care should be taken to see that the load involved at the necessary power factor is not going to have too great a disturbing effect on the circuit. Users of central station power will be required to equip their shop with expensive apparatus to meet the requirements of high power factor, insisted upon by the company supplying the electric energy. They, however, should not be frightened over this question of power factor unless they expect to consume a large amount of power for welding, as in the case of more or less isolated shop equipment, as this becomes of small importance and portability, convenience, reliability, and efficiency are the real considerations.

Report No. 11

British Admiralty Investigations in Electric Welding

A—Summary of opinions expressed by admiralty naval constructors.

B—Conclusions and Recommendations.

C—Analysis of Results.

D—Application to new construction.

Section A—Summary of Opinions Expressed by Admiralty

British Admiralty Investigations in Electric Welding
A—Summary of Opinions Expressed by Admiralty Naval Constructors

Extract C. P. 171144/8—

"Electric welding has been investigated exhaustively by Portsmouth Yard, and it is not considered that any useful purpose would be served by a further discussion on the subject with Devonport, and possibly the initiation of a special set of experiments at the Western Yard, designed to convince the Yard Officers as to the respective real merits for various purposes of these particular electrodes."

Extracts D. N. C.—3/1/18/—

(1) "Propose to inform Yard that it is not considered necessary to carry out special vibration and concussion tests in connection with the application of arc welding, as sufficient experience has already been obtained to establish the efficiency of a connection which has been properly arc welded—**the Admiralty are quite satisfied that arc welding is at least equal, if not superior, to the existing means of connecting two portions of a ship's structure,** or for making good a defective casting, and **corroboration of this view is continually being brought to notice.**

Further experiments on arc welding are contemplated, the results of which will be communicated later, but in the meantime Yard need be under no apprehension in applying the process in a proper manner to the class of work described in the second paragraph of Yard letter, as there is no doubt that the results obtained should be, with experienced workmen, superior to the usual process of construction, where one member of a structure is frequently seriously weakened by another member of the structure which unavoidably passes through it, e. g., a fore and aft girder cut by the beams or frames, whereas with the more extensive use of arc welding a homogeneous, lighter and more efficient combination could generally be obtained.

"Similarly, in regard to concussion and shock, it is believed that arc welding is at least equal to riveted connections, and full confidence is felt in its capabilities of sustaining shock and concussion in as efficient a manner as the present system of riveted connections."

(2) "——arc welding will inevitably occupy in future work of new construction as a means of producing more

efficient work, and saving weight, also of enabling the output per man to be considerably increased, an important factor in existing conditions, and likely to increase in importance later."

Extracts D. N. C. 3/11/17—

(1) "Officers attending from Devonport, Chatham, and Pembroke Yards agreed that while Quasi-Arc process of Electric Welding could not be advantageously adopted in all cases as a substitute for the present process of drilling, riveting, caulking, etc., yet its use would undoubtedly result in a great reduction in the amount of labor involved in such processes."

(2) "——it was agreed that all water-tight work could probably be well and efficiently performed with economy in labor, by increasing the rivet spacing as much as possible consistent with the proper closing of the work and supplementing this by Quasi-Arc welding so far as it is necessary to meet the requirements for strength and watertightness.

"In addition to this it was agreed that the process of watertesting would also be greatly facilitated with a corresponding saving in time and labor by the adoption of this practice.

"It was considered, however, that the development of the process would necessarily be gradual and would depend on the result of experience in work at the ship on a much larger scale than the experiments already carried out.

"The adoption of the proposals to the extent recommended, would, however, afford a very large field for experience, and the more general application to non-watertight work could be reconsidered at a later date if justified by such experience."

(3) "——a separate set of tests are being carried out with the object of determining the effect, if any, of corrosion and results will be reported in due course."

Extract D. N. C.—

"As stated by Yard officers these lists of suggested applications of electric welding (Vide Report No. 13) have no pretence to finality and a very large number of services where this process (electric welding) could be used with advantage would suggest themselves to a practical man handling it. In this connection it is proposed to leave the matter in the hands of Yard Officers who must be fully alive to its possibilities and to the necessity for its development, which is at present hampered by the limited plant at their disposal and want of experienced welders.

"It is proposed to deal with the comparative merits of —— Electrodes on receipt of report and also to take up the question of subjecting welded material to alternating stresses beyond the elastic limit with ——, who have the means of carrying out these tests and have offered their services in the matter."

Section B—Conclusions and Recommendations

The report of the tests carried out at Portsmouth is mainly of interest as showing that it is perfectly practicable to connect together two plates by means of Quasi Arc Welding in a superior manner to the usual process of riveting and caulking and that there are no insuperable difficulties in applying the process to a large portion of the work of new construction.

The experiments with riveted connections have thrown considerable light upon the weakness of our present system of connecting plates. The low stresses at which the seams open indicate that unless we can effect some improvement upon riveting we cannot utilize to the best advantage the material at our disposal and indeed suggest that we have already reached, if not exceeded, the stresses that riveted joints can stand with safety.

A large number of varying types of connection were tried, but for simplicity, reliability and general application only a few of these, viz., 6, 8, 9, 11 and 12 are recommended for immediate adoption for work at the ship pending further practical experience with this class of work.

The Yards have dealt at some length with the question of cost and have compared in detail the cost of arc welding with that of rivetting and the former has, as would be expected, shown up somewhat unfavorably. It is contended that this comparison, although interesting, is really of little value as in the case of riveting it may be said, we have had a half century's experience with it on all classes of work and that there is little or nothing to learn about riveting. In the case of arc welding, there has hitherto been no application of the process for structural work, and the initial experimental work is necessarily more costly than any alternative well established process. These facts are mentioned as it is considered that, at this stage, the excess cost of the research work should be disregarded and should not influence any decision that might be arrived at as regards applying the process.

The main considerations which justify the immediate adoption of arc welding, so far as welders and plant are available, may be summed up as follows:

(A) There is the prospect of a considerable economy of weight in limiting laps, edges and straps which in any large ship in bottom plating, e. g., are quite 20% of the total weight of shell plating, an item of considerable

moment when the shell plating of "HOOD" weighs nearly 3,000 tons.

(B) It is believed that ultimately the cost of connecting up the various parts of a ship's structure would not be largely in excess of the present process of riveting and the cost of labor would be about 25% of the total cost instead of 60 to 65% as at present, e. g., one operator would do the same work as now done by a squad of riveters (say 4 or 5 men) and a caulker.

(C) It affords a means of attaching fittings to W. T. bulkheads without piercing the bulkheads.

(D) It would be quite practicable to substitute welding for some simple but very expensive smithwork such as angle collars around frames, etc.

(E) It should simplify the obtaining of "oil tightness," saving large quantities of injection and ease the present acute situation in regard to water testing.

(F) It will ease the situation as regards the use of oxy-acetylene gases. Arc welding could to a large extent replace this process for practically all minor fittings, particularly for cutting away work although this is somewhat slower than with acetylene.

(G) Its use for repairing defective casting and plugging armor plates has already been established and doubtless as soon as experience and confidence are obtained a large number of services would suggest themselves to men handling the process.

(H) No reason is seen why female labor would not with advantage be trained to use it and in this respect it has a great advantage over the laborious process of hand riveting.

In support of the above views attention is called to the remarks of Yard Officers in heavy type. (Extracts D. N. C.—3-1-18.)

On other papers Yard Officers have made definite proposals for utilizing the process of Arc Welding for work of new construction and these proposals have been supplemented by instruction to the Yard to adopt some of the types of connection, viz., Fig. 9, 11 and 12 for bulkhead construction which by experiment have been found to be eminently suitable for this process and which can be subjected to a severe testing during the building stage.

The report indicates that a certain amount of unreliability may be expected when the process is applied to thick plates in which case more than one run of welding must be made this is due to the slag not being properly removed, thus producing porosity. On this account it would not be advisable with our present limited experience to connect thick plates together by means of arc welding although this is, of course,

fully contemplated when we have more experience and confidence in the results, it being observed that in the electrode produced by Mr. Jones it is claimed that by nickel-plating the electrode it is possible to substantially reduce the slag forming component of the insulating material.

The disadvantages of the process referred to on page 17, of the Yard Report, are fully realized, but these do not appear to be any greater than might have been expected—it will be noted that Yard are fairly confident—that with experience the various disabilities will be ultimately overcome and but for the demand for the use of the welders and plant upon what might be described as its subsidiary uses the Yard would be prepared to utilize it more extensively for work of a structural nature.

Action has been taken to refer Portsmouth Report to the other Building Yards, representatives of which conferred with Portsmouth, to prepare proposals for immediately adopting the arc welding for a number of minor services. This has been received on D. 002348/17 but the reports from other Yards have not added much to our knowledge on the subject and call for no special comment.

In conclusion, it is considered that with our present experience we are quite justified in adopting arc welding as a means of supplementing existing shipyard appliances to be used **firstly** on fittings of minor importance where great strength is not essential; **secondly,** as a more efficient means of securing water or oil tightness and inasmuch as welding contributes to the strength of the union, to proportionately reduce the connecting rivets and finally, when sufficient experience has been obtained, to use the process to replace to a large extent the present laborious process of riveting, the disabilities and limitations of which have been referred to previously.

With the above object in view it will be necessary to very largely increase the numbers of welders, welding plant and probably also the generating plant at the dockyards and with the prospective shortness of labor and the necessity of furnishing existing labor supplies with the means of performing the maximum amount of work even at the expense of material, it is considered that immediate steps should be taken by all building Yards to put the process of arc welding on a proper footing or basis, proportionate to its potentialities, observing, up to the present, there have been no failures whatever in its application—a fact to which we are indebted to the great assistance afforded us by the Q. A. Co., to whom some recognition of their service in the matter should be sent.

Section C—Report of Tests Made at Portsmouth Dockyard, England, by Direction of Director of Naval Construction Admiralty August-October, 1917

QUASI-ARC WELDING TESTS

Analysis of Results

In accordance with Admiralty Letter 15/8/17, D. 07862 17/13321 (18485), comparative tests on riveted joints and joints welded by the Quasi-Arc process have been carried out at this Yard. As the tests proceeded many modifications to the types of joints indicated in the enclosure to the order referred to, and also many additional types of joints were suggested as a result of experience and the results of the whole of the tests carried out are shown on the accompanying prints. (See Page 155).

As it was desired, as far as possible, to reproduce the conditions under which plates would be welded together in ship construction, which necessitated the welding being done in various positions, it was considered desirable that the whole of the welding should be done by an experienced operator, as the welders at this yard had had little or no experience with any type of welding other than performed in a downward direction referred to later as Flat Welding.

The whole of the welding of the test pieces for which results are shown on these sheets (with the exception of Sheet 1B) were, therefore, carried out by an operator loaned by the Quasi-Arc Company, but for the purpose of comparison a few of the tests have been repeated, the welding being done by a Dockyard operator, and the result of these tests is shown on Sheet 1B. (See end of report.)

The test pieces for which results are shown on Sheets 1, 1A, and 1B, were prepared as shown on Sheet "A."

The butt of the plates was about 2 feet in length and was welded in the following three different ways: One 8-inch length was welded with the plane of the plates horizontal, the second 8 inches with the plates in a vertical plane and the butt vertical, and the remaining 8 inches with the plane of the plates vertical and the butt horizontal. These different types of welding will be referred to as Flat, Vertical and Horizontal Welding respectively.

After welding, one tensile and two bending strips were cut out of each 8-inch length, except in the case of the 25-lb. plate with strip under, in which two tensile and one bending piece were cut out, extra test pieces being afterwards prepared for additional bending samples. The two bending strips for each type of welding were bent in opposite directions so as to test the connection on both sides of the plate.

The results of the tensile tests are shown in tons per square inch, the sections in all cases being taken as the section of the original plate. In the case of the plates with a strip welded on, this method of measuring the stress is somewhat misleading since the sectional area of the weld is greater than that of the original plate. On the other hand, however, the actual stress on the weld at the surface is appreciably increased owing to the bending effect due to the line of pull being not quite central.

The loads shown in the bending tests are the actual loads applied at the center of a 7-inch span, the diameter over which the bending took place being 4 inches in all cases.

The elongation obtained in the tensile tests was in nearly all cases small compared with that usually obtained with an ordinary tensile test on a plate. This is explained by the fact that since all specimens broke at the weld, the breaking stress of the plate had not been reached, and consequently, the final drawing out which occurs throughout an ordinary piece just before breaking, especially the region of the fracture, did not occur.

Judging from the results of the V butts as a whole, and taking cost and strength into consideration, it appears that Flat Welding is the most satisfactory method, that Vertical and Horizontal Welding are about equal in strength, but that the latter is the cheaper method.

With regard to the joint with a parallel opening and a strip on one side, the relative cost of the Flat Weld is increased owing to the overhead welding which has to be done on the strip, but neglecting the welding of the strip in each case, so as to obtain a comparison of the relative tests of welding a parallel opening, the order as regards cheapness is Flat, Vertical and Horizontal.

This is a difficult joint to weld horizontally, and the results obtained are not so satisfactory as with the other types of welding, the tensile strength in one case being only 14.8 tons per square inch.

From both a strength and cost point of view, therefore, joints such as those above, with a parallel opening, cannot be recommended for use in such positions that the welding has to be done horizontally.

The test pieces Veed from both sides of the plate were prepared with the expectation that a reduction in the cost

of welding would result, but it was found that the cost was not affected to any extent, and as a great deal of work would be involved in planing necessitating the plate being set twice in the planing machine, this type of joint has nothing to recommend it.

None of these joints could be applied to ship construction without certain modifications, and the results are mainly interesting as representing the degree of adhesion which it is possible to obtain between the plate and the added metal.

Sheets 2 and 2A show the results of experiments made with various types of welded laps with 20-lb. plating, their strength and proportion being compared with those of a single and double riveted lap.

The first type of welded lap, Fig. 3, was made with a heavy weld along each edge. Three of these were made, and with Flat Welding on one edge and Overhead Welding on the other, one with Vertical Welding, and one with Horizontal Welding on one edge and Overhead Welding on the other.

All these pieces fractured through the plate at the two rivet holes, securing the doubling pieces at the ends, the welds remaining intact.

In order to determine whether such a connection was stronger than the actual plate without any reduction due to rivet holes another test piece with a heavy weld was prepared, the ends being extended as Fig. 4. This joint broke at a load of 111 tons on a width of 10 inches, all the other laps being 12 inches long, which is equivalent to a stress on the plating of 22 tons per square inch, and this connection is thus much stronger than any type of riveted lap in common use, and very nearly equal in strength to the actual plating.

In the above laps no provision was made for connecting the plates together before welding.

This type of weld was therefore repeated on a lap as Fig. 5, in which the plates were bolted together by two bolts, 9 inches apart, before welding, the width of the laps being reduced to 2½ inches.

The edges were then welded and the holes afterwards riveted. This lap also broke through the plate in a similar way as Fig. 3, at a load of 111 tons which indicates that riveting after welding does not seriously affect the strength of the weld.

All these laps, however, are of considerably greater cost than that of a double riveted lap and further experiments were therefore made with a view to ascertaining to what extent the welding could be reduced without unduly weakening the joint.

With this object, the test piece shown in Fig. 6, was prepared, in which two bolts were again used for connecting the pieces before welding, but the lap was welded along one edge only, the thickness of the weld being the same as in the previ-

ous test pieces. The breaking strength of this lap was 74 tons, midway between the strengths of a single and a double riveted lap.

In order to ascertain whether the spacing of the rivets had any effect on the strength of this type of joint another lap, as Fig. 7, was prepared in which the rivets were placed at watertight spacing, the thickness of the weld being identical with that in the last lap. This lap broke at 71 tons, a lower result than was obtained with only two rivets.

The cost of these joints is still greatly in excess of that of a double riveted lap and with a view to a further reduction in cost, a lap was prepared as Fig. 8, in which the rivets were placed at watertight spacing and welded along one edge with a single run of welding, using a No. 10 electrode, all the other laps having been welded with two runs, one of No. 10 and one of No. 8.

The cost was thus greatly reduced and the breaking strain was 86 tons, a higher result than was obtained with a heavy weld, viz., 71 tons.

This result is much greater than was expected, judging from previous results, and in order to obtain further information with regard to the strength of a single run of welding, a lap, as Fig. 9, was prepared with only two rivets and a single run along one edge, which in this case was horizontal.

This lap broke at 67 tons against 74 tons with a heavy weld.

The result of 86 tons was considered to be exceptional and was therefore repeated using the same size electrode which gave a result of 66 tons (Fig. 14), but it was found that the thickness of the weld at the fracture was less than that of the previous lap.

It is not by any means certain that the rivets in these joints give any assistance to the weld since, the quantity of added metal being so small, very little extension of the joint takes place before breaking, consequently, unless the rivets are a perfect fit in the holes, they would probably take little or none of the stress, but would simply shear after the weld broke.

It is possible that the riveting on the lap which broke at 86 tons may have been superior to that in the other laps, in which case the rivets would come into shear with the slightest extension and so take some of the stress off the weld.

Assuming that this is the case, the results on the laps welded on one edge show that little, if any, advantage is gained by the application of more than one run, and certainly the advantage gained is not sufficient to justify the extra cost.

With regard to the spacing of the rivets, as already stated, the action of the rivets appears uncertain, and it is

therefore not considered necessary to space them more closely than is essential for ensuring that the plates are properly closed before welding, say about 8 inches.

Taking the result of these five tests together, the results show that a lap with a single or double run of welding on one edge cannot be depended upon for a strength of more than about 70 tons, which is lower than that of a double-riveted lap.

The effect of using a larger electrode on this type of joint is shown in Fig. 14, in which an exactly similar lap was welded along one edge only with a single run of a No. 8 electrode. This resulted in the thickness of the weld being increased, but it was only about the same thickness as the double run in Fig. 7. The strength, however, was nearly 50% greater, viz., 103 tons, and the structure at the fracture was more homogeneous than with the double run. This may be the reason for the great difference in strength, but on the other hand it may be a case in which the rivets were assisting in the strength of the joint.

On the whole, the results for laps with welding along one edge only are not sufficiently consistent to recommend their adoption in place of double-riveted laps, and with a view to increasing the strength of the lap and still keeping the cost as low as possible, a lap, as Fig. 10, was next prepared, in which a single run of No. 10 electrode was made on each edge of the lap. This gave a result of 101 tons which is slightly greater than that of a double-riveted lap, the stress on the plating itself being about 17 tons per square inch.

The cost of this lap is still rather excessive as compared with a double-riveted lap but the width of the lap is less, resulting in a saving in material and in weight. On the other hand this joint was welded vertically which is the most economical method of welding a lap.

With a view to a further reduction in the amount of welding, another lap was made as Fig. 11, the test piece being fixed in a vertical plane with the edges of the lap horizontal. A single run was then applied to the upper edge and a run 4 inches in length on the lower edge.

The strength of this joint, as would be expected, is less than that of a lap with a continuous run on each edge, but taking into account the awkward nature of the welding the result is considered very satisfactory.

The cost of this joint is also less than that of the last test piece in spite of the difficulty in welding overhead, but this is due to the weld being lighter than in the preceding lap.

This test piece was intended to represent a 12-inch length of a lap welded continuously on one edge and welded in 4-inch lengths on the other edge with 4-inch spaces between the

welds, but only a certain portion of such a lap is represented. Thus, the 12-inch length immediately adjacent would be represented by Fig. 12, the strength of which is 88 tons, but the cost of electrodes is less than the previous lap which indicates a lighter weld and it may therefore be assumed that such a lap would have an average strength of about 90 tons per foot length.

A joggled lap was also tried with a single run in the joggle, as shown in Fig. 13, but the result obtained was about the same as for laps with a run along one edge.

Fig. 15 represents a test on 40-lb. plating, a single-riveted lap being pulled against a welded lap. The rivets sheared at 65 tons so that the strength of the weld is not known. It is evident that too much weld had been applied for the purpose, the cost being excessive.

The next series of tests shown on Sheets 3 and 3A were made on riveted and welded butts. Single, double and treble-riveted butts were tested with the results shown in Figs. 16 to 19. In most of the riveted joints it was found that in addition to the caulks opening, due to bending, a certain amount of slip occurred in the rivets, this being demonstrated by making saw cuts at the edge of the lap or butt prior to testing. This was considered to be due to the rivets not entirely filling the holes, and to test this assumption a treble-riveted butt strap was prepared and hydraulically riveted. It was found, however, that the slipping still occurred, and it is therefore concluded that it is due to the plates cutting into the rivets before shearing. The breaking strength of this joint was also practically identical with that of the hand-riveted butt.

In comparison with these butts, three different types of welded butts were tried, the first being an ordinary V-weld; as Fig. 20, which broke through the weld at 113 tons.

In this joint there is no means of connecting the plates together before welding, and to avoid this difficulty and also avoid Veeing the butts, a joint, as shown in Fig. 21, was made in which the butts of the plates are rough-sheared and a single-riveted butt strap provides the necesary connection before welding. This strap was made of the same thickness as the plating so as to assist in keeping the ends of the plates straight and the opening between the plates, which was about ⅜-inch, was filled in by vertical welding.

In this case, the test piece broke through one of the rows of rivets at 118 tons, the weld remaining intact. This corresponds to a stress on the whole section of the plate of about 20 tons per square inch.

A similar joint was next made as Fig. 22, with only two rivets 9 inches apart to secure the plates to the strap. This gave a result of 117 tons, the joint breaking partially through

the weld and partially through the plate as shown. A repeat of this butt with Flat Welding gave a result of 116 tons, the plate breaking as shown in Fig. 24.

The difference in the method of breaking may be due to the rivets in the first and third butt assisting the weld, but in any case there does not appear to be any advantage in spacing the rivets in this type of joint closer than is necessary for closing the plates, the same conclusion as was drawn for laps.

In order to reduce the cost of such a butt, a test piece, as Fig. 25, was prepared in which the plate is Veed through only half its thickness, the edges being rough-sheared. The cost of the welding is thereby greatly reduced and the strength of the joint is seen to be greater than that of a simple-riveted butt.

Fig. 23 shows an experiment carried out to test the practicability of stopping leaks in an ordinary riveted butt which has opened by straining of the ship.

For this purpose, a narrow strip of 5-lb. plate was slightly dished and welded over the joint of the two plates, the object being to allow the joint to open while the stretched thin plate maintained the watertightness.

The result was entirely successful, as although the butt had opened 3/32" at 90 tons, the weld remained intact. It is understood that this type of joint is being used at present on one of H. M. Ships.

A further series of experiments shown on Sheets 4 and 4A was carried out on plates connected at right angles by means of welding, the strength being compared with that of riveted connections.

The resistance to bending was tested by means of small samples, as Figs. 26 to 28, which were placed in compression in the testing machine, the loads and corresponding deflections being measured. These results show that a right-angled connection with a weld in each corner resists bending equally with a connection made with riveted angle bars.

The larger test pieces in Figs. 29 to 33 were prepared for tensile tests and the results for riveted connections are seen to be low as compared with the welded joints.

In the riveted pieces the caulk at the root of the angles opened at 15 tons, rendering the joint non-watertight, whereas the welded joints necessarily remain watertight up to the breaking load.

This remark, however, applies to all types of welded joints, and although in many cases the ultimate strength of a welded connection is less than that of a riveted one, the loads at which the riveted joints begin to open are invariably much lower than the breaking strain of even the weakest welded joint.

With regard to the tests of welding performed by a Dockyard operator (Sheet 1B), it will be seen that with 25-lb. plating there is little difference in the strength on these welds as compared with those done by the Quasi-Arc Company's operator.

The comparisons with 40-lb. plate are not so good, particularly in the case of the horizontal welds. In fact, in all cases the fractures showed that the slag had not been properly worked out of the weld.

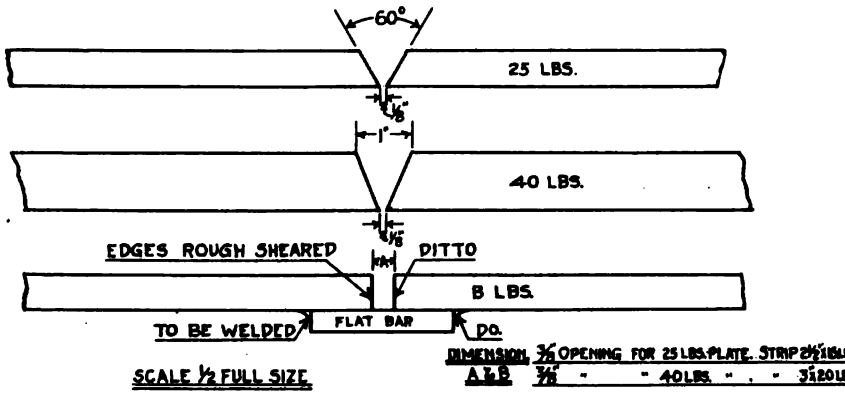
These results show the necessity of thoroughly training all operators in the different types of welding before they can be depended upon to produce consistently good results.

With regard to the test referred to, in which a single run of No. 8 electrode was used (See Fig. 14), this was one of the last tests made, and throughout the whole series of tests with laps, and right-angled connections, it was the only case in which this type of electrode had been used for a first run. In all other cases the weld had been started with a No. 10 electrode, this being the practice recommended by the company's representatives in order to obtain an efficient weld in the corners of the joints. It would appear from this result, however, that for the same cost of electrodes a stronger weld is obtained, with a lap, by the use of a No. 8 electrode and the same might also apply to right-angled connections. This point is being taken up with the Quasi-Arc Company and further tests are being arranged for.

ELECTRIC WELDING TESTS.—QUASI-ARC METHOD.

METHOD OF PREPARATION OF BENDING AND TENSILE STRIPS.

REFERRED TO ON SHEET I SHEET.A.



TYPICAL PLATE.

SCALE ¼ FULL SIZE

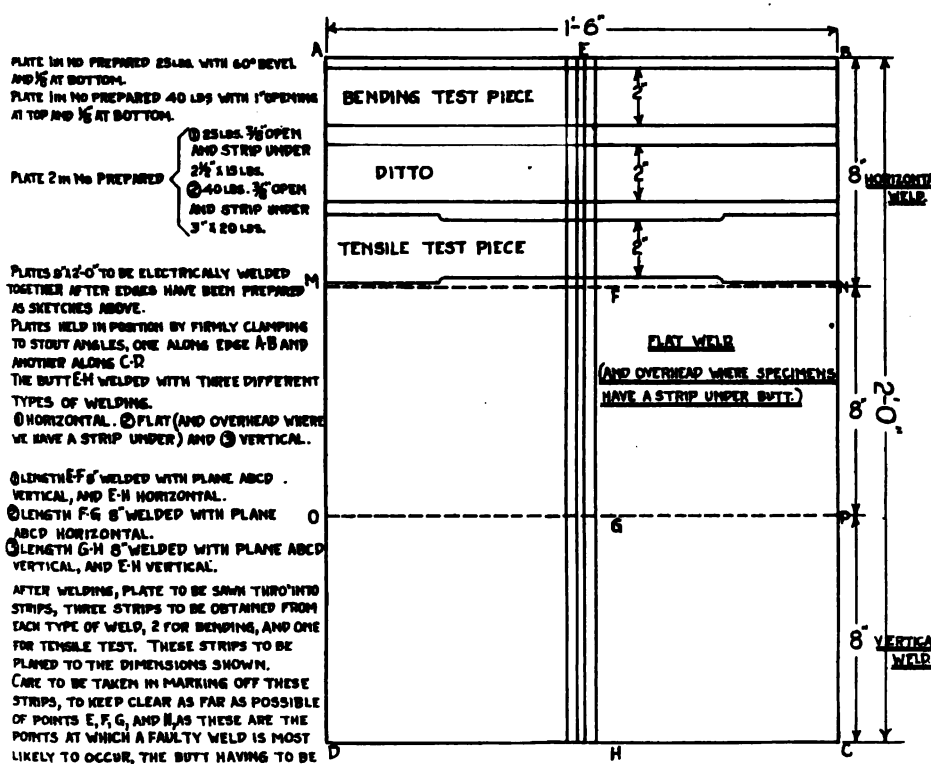


PLATE 1 in No PREPARED 25 LBS. WITH 60° BEVEL AND 1/8 AT BOTTOM.
PLATE 1 in No PREPARED 40 LBS WITH 1" OPENING AT TOP AND 1/8 AT BOTTOM.

PLATE 2 in No PREPARED
① 25 LBS. 3/16 OPEN AND STRIP UNDER 2½" x 15 LBS.
② 40 LBS. 3/8" OPEN AND STRIP UNDER 3" x 20 LBS.

PLATES 8"x2'-0" TO BE ELECTRICALLY WELDED TOGETHER AFTER EDGES HAVE BEEN PREPARED AS SKETCHES ABOVE.
PLATES HELD IN POSITION BY FIRMLY CLAMPING TO STOUT ANGLES, ONE ALONG EDGE A-B AND ANOTHER ALONG C-D.
THE BUTT E-H WELDED WITH THREE DIFFERENT TYPES OF WELDING.
① HORIZONTAL. ② FLAT (AND OVERHEAD WHERE WE HAVE A STRIP UNDER) AND ③ VERTICAL.

① LENGTH E-F 8" WELDED WITH PLANE ABCD VERTICAL, AND E-H HORIZONTAL.
② LENGTH F-G 8" WELDED WITH PLANE ABCD HORIZONTAL.
③ LENGTH G-H 8" WELDED WITH PLANE ABCD VERTICAL, AND E-H VERTICAL.

AFTER WELDING, PLATE TO BE SAWN THRO' INTO STRIPS, THREE STRIPS TO BE OBTAINED FROM EACH TYPE OF WELD, 2 FOR BENDING, AND ONE FOR TENSILE TEST. THESE STRIPS TO BE PLANED TO THE DIMENSIONS SHOWN.
CARE TO BE TAKEN IN MARKING OFF THESE STRIPS, TO KEEP CLEAR AS FAR AS POSSIBLE OF POINTS E, F, G, AND H, AS THESE ARE THE POINTS AT WHICH A FAULTY WELD IS MOST LIKELY TO OCCUR, THE BUTT HAVING TO BE PINNED AT THESE POINTS BEFORE WELDING PROPER IS COMMENCED

ELECTRIC WELDING TESTS.– QUASI-ARC METHOD.

BENDING AND TENSILE TESTS – TEST PIECES 2" WIDE.

STATEMENT OF COST AND TESTS APPLIED. SHEET 1.

NOTE:– TONS ARE FIGURED AS LONG TON OF 2240 POUNDS.

SECTION OF SPECIMEN. STRIP 2" WIDE — 60° — 25 LBS. — 1¼" OPEN

SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X= BOTTOM OF V IN TENSION.
Y= BOTTOM OF V IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING PER SQUARE INCH YIELD	BENDING PER SQUARE INCH BREAK	ANGLE
HORIZONTAL WELD	14·1 TONS OR 31020 LBS.	25·36 TONS OR 55792 LBS.	X 8·57 TONS OR 19234 LBS.	X 9·54 TONS OR 17788 LBS.	25°
			Y 2·18 TONS OR 4796 LBS.	Y 4·01 TONS OR 8982 LBS.	38°
FLAT WELD	16·51 TONS OR 36322 LBS.	24·75 TONS OR 54450 LBS.	X 2·32 TONS OR 5140 LBS.	X 2·68 TONS OR 5004 LBS.	30°
			Y 2·48 TONS OR 5390 LBS.	Y 3·54 TONS OR 7768 LBS.	26°
VERTICAL WELD		24·34 TONS OR 53548 LBS.	X 1·37 TONS OR 3074 LBS.	X 3·51 TONS OR 7810 LBS.	23°
			Y 850 TONS OR 1920 LBS.	Y 1·43 TONS OR 3190 LBS.	18°

SECTION OF SPECIMEN. STRIP 2" WIDE — 25 LBS. — ARC WELD

SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X= STRIP IN TENSION.
Y= STRIP IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING PER SQUARE INCH YIELD	BENDING PER SQUARE INCH BREAK	ANGLE
HORIZONTAL WELD	18 TONS OR 39600 LBS.	20·6 TONS OR 45320 LBS.	X 4·47 TONS OR 9834 LBS.	X 6·84 TONS OR 15324 LBS.	26°
	—	14·81 TONS OR 32582 LBS.	Y 4·9 TONS OR 10780 LBS.	Y 6·22 TONS OR 13684 LBS.	12°
FLAT AND OVERHEAD WELD	—	27·37 TONS OR 60214 LBS.	X 411 TONS OR 9042 LBS.	X 6·57 TONS OR 14454 LBS.	0°
	18·4 TONS OR 40480 LBS.	26·36 TONS OR 58004 LBS.	Y 3·0 TONS OR 6600 LBS.	Y 9·39 TONS OR 20666 LBS.	60°
VERTICAL WELD	—	23·21 TONS OR 51062 LBS.	X 2·0 TONS OR 4400 LBS.	X 7·17 TONS OR 15774 LBS.	39°
	19·04 TONS OR 41888 LBS.	21·42 TONS OR 47124 LBS.	Y 4·54 TONS OR 9988 LBS.	Y 7·82 TONS OR 17204 LBS.	32°

COST OF 8" LENGTH OF ABOVE WELD.

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST
HORIZONTAL WELD	s d 1 – 2½ OR £ ·29	s d 3 – 6 OR £ ·88	AMPS. 110 FOR 40 MINS. VOLTS 100	d OR £ ·10	s d 1 – 4·5 OR £ 1·27
FLAT WELD	s d 1 – 3½ OR £ ·41	s d 3 – 0 OR £ ·73	AMPS. 100 FOR 40 MINS. VOLTS 100	d OR £ ·10	s d 1 – 4·5 OR £ 1·14
VERTICAL WELD	s d 1 – 4 OR £ ·32	s d 4 – 11½ OR £ 1·31	AMPS. 120 FOR 40 MINS. VOLTS 100	d 4½ OR £ ·13	s d 1 – 8·5 OR £ 1·66

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST	COST REDUCTION WELDING OF STRIP
HORIZONTAL WELD	s d 1 – 4½ OR £ ·36	s d 5 – 5 OR £ 1·34	AMPS. 110 FOR 40 MINS. VOLTS 100	d OR £ ·19	s d 2 – 0·5 OR £ 1·55	s d 2 – 0·5 OR £ 1·55
FLAT AND OVERHEAD WELD	s d 1 – 3 OR £ ·25	s d 7 – 7 OR £ 1·84	AMPS. 100 FOR 40 MINS. VOLTS 100	d 10½ OR £ ·21	s d 2 – 0 OR £ 2·60	s d 3 – 2½ OR £ 2·70
VERTICAL WELD	s d 1 – 4 OR £ ·32	s d 5 – 11 OR £ 1·44	AMPS. 100 FOR 40 MINS. VOLTS 100	d 8½ OR £ ·11	s d 1 – 7·5 OR £ 1·87	s d 4 – 12 OR £ 1·76

SECTION OF SPECIMEN. — 40 LBS. — 1/8 OPEN

SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X= BOTTOM OF V IN TENSION.
Y= BOTTOM OF V IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING PER SQUARE INCH YIELD	BENDING PER SQUARE INCH BREAK	ANGLE
HORIZONTAL WELD	14·18 TONS OR 31,196 LBS.	18·69 TONS OR 41,118 LBS.	X 5·51 TONS OR 12,122 LBS.	X 6·68 TONS OR 14,696 LBS.	8·5°
			Y 5·65 TONS OR 12,430 LBS.	Y 8·68 TONS OR 19,096 LBS.	23°
FLAT WELD	13·17 TONS OR 28,974 LBS.	21·44 TONS OR 47,168 LBS.	X 5·26 TONS OR 11,616 LBS.	X 8·20 TONS OR 18,038 LBS.	28°
			Y 5·74 TONS OR 12,628 LBS.	Y 7·46 TONS OR 16,412 LBS.	23°
VERTICAL WELD	12·95 TONS OR 28,490 LBS.	18·95 TONS OR 41,690 LBS.	X 5·71 TONS OR 12,562 LBS.	X 8·34 TONS OR 18,348 LBS.	29°
			Y 5·10 TONS OR 11,220 LBS.	Y 9·11 TONS OR 20,042 LBS.	31·5°

SECTION OF SPECIMEN. — 40 LBS. — 3"x½ STRIP UNDER. — ARC WELD

SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X= STRIP IN TENSION.
Y= STRIP IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING PER SQUARE INCH YIELD	BENDING PER SQUARE INCH BREAK	ANGLE
HORIZONTAL WELD	13·95 TONS OR 30,690 LBS.	22·425 TONS OR 49,335 LBS.	X 13·09 TONS OR 28,798 LBS.	X 20·86 TONS OR 45,892 LBS.	43·5°
			11·18 TONS OR 24,596 LBS.	18·13 TONS OR 39,886 LBS.	4°
FLAT AND OVERHEAD WELD	13·7 TONS OR 30,140 LBS.	22·94 TONS OR 49,568 LBS.	X 10·85 TONS OR 24,112 LBS.	13·9 TONS OR 31,000	APPROX 14°
			Y 10·0 TONS OR 22,000 LBS.	14·73 TONS OR 32,406 LBS.	17°
VERTICAL WELD	14·56 TONS OR 32,032 LBS.	24·5 TONS OR 54,010 LBS.	X 8·84 TONS OR 19,448 LBS.	14·81 TONS OR 32,582 LBS.	31°
			Y 6·45 TONS OR 14,190 LBS.	13·84 TONS OR 30,448 LBS.	12·5°

COST OF 8" LENGTH OF ABOVE WELD.

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST
HORIZONTAL WELD	s d 2 – 4½ OR £ ·58	s d 8 – 5½ OR £ 2.06	AMPS. 140 FOR 66 MINS. VOLTS 100	d 10¾ OR £ ·22	s d 11 – 0 OR £ 2.86
FLAT WELD	s d 1 – 7 OR £ ·38	s d 4 – 11 OR £ 1.20	AMPS. 160 FOR 38 MINS. VOLTS 100	d 7¾ OR £ ·15	s d 7 – 1 OR £ 1.72
VERTICAL WELD	s d 3 – 1½ OR £ ·76	s d 9 – 0 OR £ 2.19	AMPS. 140 FOR 69 MINS. VOLTS 100	d 11¾ OR £ ·24	s d 13 – 1 OR £ 3.16

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST	COST REDUCTION WELDING OF STRIP
HORIZONTAL WELD	s d 5 – 0 OR £1.22	s d 16 – 0 OR £ 3.89	AMPS. 110 FOR 136 MINS. VOLTS 100	s d 1 – 3½ OR £ .35	£ s d 1 – 2 – 5½ OR £ 5.46	s d 14 – 2 OR £ 3.45
FLAT AND OVERHEAD WELD	s d 4 – 8½ OR £1.14	s d 12 – 1 OR £ 2.94	AMPS. 130 FOR 184 MINS. VOLTS 100	s d 1 – 6¾ OR £ .36	s d 18 – 4 OR £ 4.46	s d 8 – 11 OR £ 2.17
VERTICAL WELD	s d 2 – 4½ OR £ .58	s d 10 – 9 OR £ 2.62	AMPS. 120 FOR 85 MINS. VOLTS 100	d 11¾ OR £ .24	s d 14 – 1 OR £ 3.43	s d 9 – 8 OR £ 2.35

ELECTRIC WELDING TESTS - QUASI-ARC METHOD.

BENDING AND TENSILE TESTS - TEST PIECES 2" WIDE.

STATEMENT OF COST AND TESTS APPLIED. SHEET. I.A.

NOTE:- TONS ARE FIGURED AS LONG TON OF 2,200 POUNDS.

QUASI-ARC.

SECTION OF SPECIMEN

STAMPED SIDE

SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X= STAMPED SIDE IN TENSION.
Y= STAMPED SIDE IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING ACTUAL LOAD YIELD	BENDING ACTUAL LOAD BREAK	ANGLE
HORIZONTAL WELD	13.79 TONS OR 30,336 LBS.	24.04 TONS OR 52,888 LBS. 27½% ELONG.	X 8.7 TONS OR 19,140 LBS.	9.76 TONS OR 21,472 LBS.	38°
			Y 8.48 TONS OR 20,812 LBS.	8.82 TONS OR 21,604 LBS.	39½°
FLAT AND OVERHEAD WELD	14.33 TONS OR 31,526 LBS.	21.7 TONS OR 47,740 LBS.	X 8.48 TONS OR 18,524 LBS.	10.27 TONS OR 22,544 LBS.	78°
			Y 8.24 TONS OR 18,128 LBS.	9.0 TONS OR 19,800 LBS.	19°
VERTICAL WELD	14.87 TONS OR 32,714 LBS.	24.34 TONS OR 53,548 LBS.	X 8.58 TONS OR 18,870 LBS.	8.48 TONS OR 19,046 LBS.	28°
			Y 7.99 TONS OR 16,648 LBS.	9.3 TONS OR 20,400 LBS.	36°

COST OF 8" LENGTH OF ABOVE WELD

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST
HORIZONTAL WELD	s d 2-8 OR $ .65	s d 7-8 OR $ 1.67	AMPS. 130 MINS FOR 61 VOLTS 95	d 8¾ OR $ .18	s d (1 MACHINE) 11-1 OR $2.70
FLAT AND OVERHEAD WELD	s d 2-9½ OR $ .68	s d 6-1 OR $ 1.48	AMPS. 130 MINS FOR 74½ VOLTS 95	d 10¾ OR $ .22	s d 9-9 OR $2.37
VERTICAL WELD	s d 3-1 OR $ .75	s d 11-10¼ OR $ 2.88	AMPS. 150 MINS FOR 99 VOLTS 96	s d 1-5¼ OR $ .35	s d 16-4½ OR $3.98

SECTION OF SPECIMEN.

HIGH TENSILE

SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X= BOTTOM OF V IN TENSION.
Y= BOTTOM OF V IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING ACTUAL LOAD YIELD	BENDING ACTUAL LOAD BREAK	ANGLE
HORIZONTAL WELD	14.65 TONS OR 32,230 LBS.	21.12 TONS OR 46,464 LBS. 5.5% ELONG.	X 8.82 TONS OR 19,224 LBS.	8.46 TONS OR 18,612 LBS.	23½°
			Y 7.1 TONS OR 15,620 LBS.	7.76 TONS OR 17,072 LBS.	13°
FLAT WELD	17.18 TONS OR 37,796 LBS.	27.15 TONS OR 59,730 LBS. 5.25% ELONG.	X 10.37 TONS OR 22,814 LBS.	11.18 TONS OR 24,596	24°
			Y 5.35 TONS OR 11,770 LBS.	6.56 TONS OR 14,432	18°
VERTICAL WELD	14.27 TONS OR 31,394 LBS.	19.74 TONS OR 43,428 LBS.	X 7.55 TONS OR 16,598 LBS.	9.51 TONS OR 20,922 LBS.	10°
			Y 10.46 TONS OR 23,012 LBS.	11.25 TONS OR 24,706 LBS.	29°

COST OF 8" LENGTH OF ABOVE WELD

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST
HORIZONTAL WELD	s d 3-0½ OR $ .74	s d 7-11 OR $1.93	AMPS. 123 MINS FOR 88 VOLTS 102	s d 1-0¾ OR $ .26	s d (1 MACHINE) 12-0 OR $2.92
FLAT WELD	s d 2-9¼ OR $ .67	s d 7-4 OR $ 1.78	AMPS. 103 FOR 73⅓ VOLTS 99	d 9 OR $ .18	s d 10-10 OR $2.64
VERTICAL WELD	s d 2-7 OR $ .63	s d 11-2½ OR $ 2.73	AMPS. 133 FOR 87½ VOLTS 100	s d 1-1½ OR $ .27	s d 14-11 OR $3.63

ELECTRIC WELDING TEST. (Q.A.D)

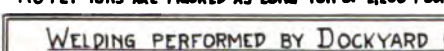
BENDING AND TENSILE TESTS – TEST PIECES 2" WIDE.

STATEMENT OF COST AND TESTS APPLIED. SHEET. I. B.

NOTE:- TONS ARE FIGURED AS LONG TON OF 2,200 POUNDS

WELDING PERFORMED BY DOCKYARD OPERATOR USING Q.A. ELECTRODES.

SECTION OF SPECIMEN.



SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X- BOTTOM OF V IN TENSION.
Y- BOTTOM OF V IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING ACTUAL LOAD YIELD	BENDING ACTUAL LOAD BREAK	ANGLE
HORIZONTAL WELD	18·80 TONS OR 41,360 LBS	20·06 TONS OR 44,132 LBS	X 2·62 TONS OR 5,764 LBS Y 2·95 TONS OR 6,490 LBS	X 3·3 TONS OR 7,260 LBS Y 3·57 TONS OR 7,854 LBS	24½° 30°
FLAT WELD	19·35 TONS OR 42,570 LBS	23·0 TONS OR 50,600 LBS	X 2·41 TONS OR 5,302 LBS Y 2·68 TONS OR 5,896 LBS	X 2·81 TONS OR 6,182 LBS Y 3·53 TONS OR 7,766 LBS	16½° 38½°
VERTICAL WELD	19·12 TONS OR 42,064 LBS	24·64 TONS OR 54,208 LBS 4¼" ELONG"	X 2·74 TONS OR 6,028 LBS Y 3·23 TONS OR 7,106 LBS	X 3·04 TONS OR 6,688 LBS Y 3·55 TONS OR 7,810 LBS	22° 40°

COST OF 8" LENGTH OF ABOVE WELD.

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST
HORIZONTAL WELD	5 d. 1-10 OR $.45	5 d. 4-4½ OR $1.06	AMPS MINS 100 FOR 53½ VOLTS 100	d. 6¼ OR $.13	CONSUMED 5 d. 6-0 OR $1.24
FLAT WELD	5 d. 1-2½ OR $.29	5 d. 3-7½ OR $.88	AMPS MINS 100 FOR 34½ VOLTS 102	d. 4 OR $.08	5 d. 5-2 OR $1.25
VERTICAL WELD	5 d. 1-4½ OR $.43	5 d. 5-0 OR $1.22	AMPS MINS 130 FOR 50½ VOLTS 96	d. 7½ OR $.15	5 d. 7-5 OR $1.80

SECTION OF SPECIMEN.

SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X- BOTTOM OF V IN TENSION.
Y- BOTTOM OF V IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING ACTUAL LOAD YIELD	BENDING ACTUAL LOAD BREAK	ANGLE
HORIZONTAL WELD	—	8·67 TONS OR 19,078 LBS. LARGE AMOUNT OF SLAG IN THIS WELD.	X 4·69 TONS OR 10,318 LBS Y 6·25 TONS OR 13,706 LBS	X 4·69 TONS OR 10,318 LBS Y 7·32 TONS OR 16,104 LBS	NIL 17°
FLAT WELD	14·16 TONS OR 31,152 LBS	20·02 TONS OR 44,044 LBS	X 5·84 TONS OR 12,948 LBS Y 7·01 TONS OR 15,422 LBS	X 7·36 TONS OR 16,192 LBS Y 8·36 TONS OR 18,392 LBS	9° 23°
VERTICAL WELD	15·31 TONS OR 33,682 LBS	16·32 TONS OR 35,904 LBS	X 5·92 TONS OR 13,024 LBS Y 3·8 TONS OR 16,720 LBS	X 7·28 TONS OR 16,016 LBS Y 6·78 TONS OR 14,916 LBS	16° 10°

COST OF 8" LENGTH OF ABOVE WELD.

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST
HORIZONTAL WELD	5 d. 2-3 OR $.55	5 d. 8-0 OR $1.95	AMPS MINS 110 FOR 77½ VOLTS 102	d. 10½ OR $.21	CONSUMED 5 d. 11-1½ OR $2.71
FLAT WELD	5 d. 1-4 OR $.32	5 d. 5-5 OR $1.32	AMPS MINS 115 FOR 44 VOLTS 99	d. 6 OR $.12	5 d. 7-5 OR $1.76
VERTICAL WELD	5 d. 1-7 OR $.39	5 d. 6-5 OR $1.56	AMPS MINS 118 FOR 54 VOLTS 82	d. 7 OR $.14	5 d. 8-7 OR $2.09

SECTION OF SPECIMEN.

SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X- STRIP IN TENSION.
Y- STRIP IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING ACTUAL LOAD YIELD	BENDING ACTUAL LOAD BREAK	ANGLE
HORIZONTAL WELD	15·62 TONS OR 34,364 LBS	17·72 TONS OR 38,984 LBS	X 3·46 TONS OR 8,712 LBS Y 3·53 TONS OR 7,766 LBS	X 3·7 TONS OR 12,540 LBS Y 7·08 TONS OR 15,576 LBS	19° 43½°
FLAT AND OVERHEAD WELD	15·36 TONS OR 33,792 LBS	19·79 TONS OR 43,538 LBS	X 4·72 TONS OR 10,384 LBS Y 5·68 TONS OR 13,196 LBS	X 5·24 TONS OR 11,528 LBS Y 6·81 TONS OR 15,282 LBS	35° 35°
VERTICAL WELD	15·87 TONS OR 34,914 LBS	22·8 TONS OR 50,160 LBS	X 3·58 TONS OR 7,910 LBS Y 6·13 TONS OR 13,486 LBS	X 4·24 TONS OR 9,264 LBS Y 7·33 TONS OR 16,126 LBS	83½°

COST OF 8" LENGTH OF ABOVE WELD.

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST	COST REJECTING WELDING OR STRIP
HORIZONTAL WELD	5 d. 2-6 OR $.61	5 d. 7-7½ OR $1.90	AMPS MINS 125 FOR 72 VOLTS 100	d. 10 OR $.20	CONSUMED 5 d. 9-5½ OR $2.07	5 d. 7-8 OR $1.86
FLAT AND OVERHEAD WELD	5 d. 2-2 OR $.53	5 d. 5-6 OR $1.34	AMPS MINS 115 FOR 59 VOLTS 100	d. 9¼ OR $.17	5 d. 6-4 OR $2.05	5 d. 4-8 OR $1.68
VERTICAL WELD	5 d. 2-2¼ OR $.53	5 d. 7-4¾ OR $1.90	AMPS MINS 115 FOR 60 VOLTS 101	d. 8¾ OR $.18	5 d. 10-0 OR $2.61	5 d. 7-4 OR $1.97

SECTION OF SPECIMEN.

SAMPLES BENT OVER 7" SPAN.
LETTERS DENOTING METHOD OF BENDING.
X- STRIP IN TENSION.
Y- STRIP IN COMPRESSION.

DESCRIPTION OF WELD	TENSILE PER SQUARE INCH YIELD	TENSILE PER SQUARE INCH BREAK	BENDING ACTUAL LOAD YIELD	BENDING ACTUAL LOAD BREAK	ANGLE
HORIZONTAL WELD	—	11·25 TONS OR 24,750 LBS	X 12·66 TONS OR 27,852 LBS Y 10·54 TONS OR 23,188 LBS	X 15·2 TONS OR 33,440 LBS Y 11·8 TONS OR 25,960 LBS	24° 8°
FLAT AND OVERHEAD WELD	13·5 TONS OR 29,700 LBS	21·22 TONS OR 46,684 LBS	X 11·84 TONS OR 26,048 LBS Y 10·21 TONS OR 22,462 LBS	X 12·8 TONS OR 28,160 LBS Y 17·01 TONS OR 37,422 LBS	15½° 27°
VERTICAL WELD	14·03 TONS OR 30,866 LBS	19·4 TONS OR 42,680 LBS	X 8·8 TONS OR 19,360 LBS Y 12·44 TONS OR 27,368 LBS	X 14·21 TONS OR 31,262 LBS Y 15·83 TONS OR 35,926 LBS	16° 30½°

COST OF 8" LENGTH OF ABOVE WELD.

DESCRIPTION OF WELD	LABOUR	MATERIAL	CURRENT	COST OF CURRENT	TOTAL COST	COST REJECTING WELDING OR STRIP
HORIZONTAL WELD	5 d. 5-2 OR $1.27	5 d. 16-10 OR $4.10	AMPS MINS 120 FOR 15½ VOLTS 100	5 d. 1-10½ OR $.46	CONSUMED 5 d. 23-5 d. 1-3-11 OR $5.82	5 d. 17-7½ OR $4.28
FLAT AND OVERHEAD WELD	5 d. 4-0½ OR $.98	5 d. 10-5 OR $2.53	AMPS MINS 108 FOR 125 VOLTS 98	5 d. 1-3½ OR $.31	5 d. 15-9 OR $3.83	5 d. 7-4 OR $1.78
VERTICAL WELD	5 d. 4-7 OR $1.11	5 d. 14-11½ OR $3.64	AMPS MINS 122 FOR 145 VOLTS 99	5 d. 1-7 OR $.39	£ 5 d. 1-1-1½ OR $5.14	5 d. 15-10 OR $3.85

ELECTRIC WELDING TESTS.—QUASI-ARC METHOD.

LAP JOINTS.— DIAGRAMS 5/8" TO 1 FT.

STATEMENT OF COST AND TESTS APPLIED. SHEET 2.

NOTE:- TONS ARE FIGURED AS A LONG TON OF 2,200 POUNDS.

SKETCH AND DESCRIPTION.	LABOUR	MATERIAL	POWER CHARGE	POWER TIME	POWER COST	TOTAL COST	ACTUAL WELDING TIME	TOTAL TIME	RESULT OF TEST
VERTICAL WELDED 4" LAP V 3/4" RIVETS 4 IN NO. FIG. 1.	d. 8½ or $0.17	d. 3½ or $0.07	RIVETING COST			s d 1-0 or $0.24			Tons 20 NO MOVEMENT. 25 CAULK OPENED VISIBLY. 30 RIVETS SLIP SLIGHTLY. 52 BREAK, ALL RIVETS SHEARED.
	s d 1-2½ or $0.29	s d 5-0 or $1.22	AMPS. 105 VOLTS 92	MINS. 45	d. 5¼ or $0.11	s d 6-4½ or $1.62	MINS. 45	MINS. 46	
ORDINARY D.R. LAP 3/4" RIVETS. FIG. 2.	s d 1-1 or $0.26	d 7 or $0.14	RIVETING COST			s d 1-8 or $0.40			Tons 25 NO MOVEMENT. 30 CAULK VISIBLY OPEN. NO SLIP. 35 " " " BOTH EDGES. 40 BENDING; CAULK CONT OPENING. 50 DITTO. NO SLIP. 60 BOTH CAULKS OPEN 1/16" SLIP AT A 3/32 AT B 3/16". 86 BREAK. ALL RIVETS SHEARED.
4" LAP WELDED IN 3 POSITIONS ① HORIZONTAL ② FLAT & OVERHEAD ③ VERTICAL FIG. 3.	D.W.V. s d 2-1 or $0.51	s d 7-0½ or $1.77	AMPS. 85 VOLTS 86	MINS. 66	d. 5½ or $0.11	s d 9-7 or $2.39	MINS. 65	MINS. 80	WELD SHOWED NO MOVEMENT. PLATE BROKE THRO' A. LOAD 120 TONS.
	D.W.V. s d 2-8 or $0.65	s d 7-1½ or $1.34	AMPS. 85 VOLTS 102	MINS. 88	s d 1-0 or $0.24	s d 10-4½ or $2.63	MINS. 88	MINS. 102	WELD SHOWED NO MOVEMENT. PLATE BROKE THRO' A. LOAD 119 TONS.
	D.W.V. s d 1-4 or $0.32	s d 5-7½ or $1.37	AMPS. 115 VOLTS 96	MINS. 44	d. 5½ or $0.12	s d 7-5 or $1.81	MINS. 44	MINS. 52	WELD SHOWED NO MOVEMENT PLATE BROKE THRO' A. LOAD 111 TONS.
FIG. 4. WELDED LAP 4" WIDE. WELDED VERTICALLY	s d 1-1 or $0.26	s d 4-7 or $1.12	AMPS. 130 VOLTS 102	MINS. 42	d. 6½ or $0.13	s d 6-2½ or $1.51	MINS. 42	MINS 44	TONS 50 NO MOVEMENT. 70 SLIGHT BENDING. 85 CONTINUED BENDING. 111 BREAK—WELD AT BOTH EADGES. 133 EQUIVALENT FOR LAP 12" WIDE.
WELDED LAP 2½" WIDE WITH 3/4" RIVETS 2 IN NO. 9" APART. FIG. 5.	d. 2½ or $0.05	d. 1¾ or $0.04	RIVETING COST			d. 4 or $0.08			WELD SHOWED NO MOVEMENT. PLATE BROKE THRO' A. LOAD 111 TONS.
	s d 1-3 or $0.30	s d 5-3½ or $1.24	AMPS. 120 VOLTS 102	MINS. 42	d. 6 or $0.12	s d 7-0½ or $1.71	MINS. 42	MINS. 47½	
LAP 2½" WIDE. ONE EDGE WELDED OTHER EDGE CAULKED. 3/4" RIVETS 2 IN NO. FIG. 6.	d. 3½ or $0.07	d. 1¾ or $0.04	RIVETING COST			d. 5 or $0.10			TONS 20 NO MOVEMENT. 40 CAULKING VISIBLE. 50 CAULKING MORE VISIBLE. 74 BREAK. WELD BROKE AND RIVETS SHEARED.
	d. 9½ or $0.19	s d 2-10½ or $0.70	AMPS. 130 VOLTS 102	MINS. 25	d. 3½ or $0.08	s d 3-4½ or $0.97	MINS. 25	MINS 30	
						s d 5-4½ or $1.07			
LAP 2½" WIDE. HEAVY WELD ONE EDGE, CAULK AT OTHER. 4-3/4" RIVETS. FIG. 7.	d. 8½ or $0.17	d. 3½ or $0.07	RIVETING COST			s d 1-0 or $0.24			TONS 50 NO MOVEMENT. 60 CAULK OPEN 10/1000. 71 WELD BROKE AND RIVETS SHEARED.
	d. 6 or $0.12	s d 2-3 or $0.55	AMPS. 105 VOLTS 102	MINS 20	d. 2½ or $0.05	s d 2-11½ or $0.72	MINS. 20	MINS 20¾	
						s d 3-11½ or $0.96			
LAP 2½" WIDE. LIGHT WELD ONE EDGE, CAULKED AT OTHER. 4-3/4" RIVETS. FIG. 8.	d. 8½ or $0.17	d. 3½ or $0.07	RIVETING COST			s d 1-0 or $0.24			TONS 45 NO MOVEMENT. 50 CAULK OPEN 4/1000. 66 WELD BROKE AND RIVETS SHEARED.
	d. 3½ or $0.07	d. 10½ or $0.21	AMPS. 105 VOLTS 108	MINS. 10	d. 1½ or $0.02	s d 1-3 or $0.30	MINS. 10	MINS 10	
						s d 2-3 or $0.44			

ELECTRIC WELDING TESTS - QUASI-ARC METHOD.

LAP JOINTS — DIAGRAMS 5/8" TO 1 FT.

STATEMENT OF COST AND TESTS APPLIED

NOTE;- TONS ARE FIGURED AS A LONG TON OF 2,200 POUNDS.

SKETCH AND DESCRIPTION.	LABOUR	MATERIAL	POWER			TOTAL COST	ACTUAL WELDING TIME	TOTAL TIME	RESULT OF TEST.
				TIME	COST				
LAP 2½" WIDE. SINGLE RUN OF WELDING ON ONE EDGE, OTHER EDGE CAULKED. RIVETS ⅝ 2 IN NO. 9 APART. FIG. 9. 20 LBS. 2½"×¼ LIGHT WELD (HORIZONTAL) CAULK	d. 3¼ OR $.06; d. 3 OR $.04	d. 1¾ OR $.04; d. 10¾ OR $.12	RIVETING COST; AMPS 105 VOLTS 97	MINS 9	d. 1 OR $.02	d. 5 OR $.10; S d. 1-2½ OR $.30	9 MINS	9 MINS	TONS 20 - NO MOVEMENT. 30 - DITTO. 40 - CAULKING VISIBLE BETWEEN RIVETS 67 - BREAK, WELD BROKE AND RIVETS SHEARED
LAP 2½" WIDE. SINGLE RUN OF WELDING ON EACH EDGE, RIVETS ⅝ 2 IN NO. 9 APART. FIG. 10. 20 LBS. LIGHT WELD (VERTICAL)	d. 2¾ OR $.05; d. 7½ OR $.15	d. 1¾ OR $.04; S d. 2-3 OR $.55	RIVETING COST; AMPS 105 VOLTS 102	24 MINS	d. 3	d. 4 OR $.08; S d. 3-1¾ OR $.76; S d. 3-5¾ OR $.84	MINS 24	MINS 25	WELD BROKE AT BOTH EDGES. LOAD 101 TONS.
LAP 2½" WIDE. SINGLE RUN OF WELDING ON ONE EDGE AND A 4" LENGTH AT MIDDLE OF OTHER EDGE. ⅝ RIVETS 2 IN NO. 9. FIG. 11. A B BOTH EDGES WELDED WITH END AB ON BENCH. 20 LBS. LIGHT WELD	d. 2¾ OR $.05; S d. 5 OR $.10	d. 1¾ OR $.04; S d. 1-3 OR $.30	RIVETING COST; AMPS 105 VOLTS 105	MINS 11	d. 1½ OR $.03	d. 4 OR $.08; S d. 1-9¾ OR $.44; S d. 2-1½ OR $.52	MINS 11	MINS 16	TONS 20 - NO MOVEMENT. 91 - BREAK. BOTH WELD
LAP 2½" WIDE. SINGLE RUN OF WELDING ON ONE EDGE AND 2 IN NO. 4 LENGTHS ON OTHER EDGE. ⅝ RIVET LINE. FIG. 12. A B BOTH EDGES WELDED WITH END AB ON BENCH. 20 LBS. LIGHT WELD	d. 1 OR $.02; d. 5½ OR $.11	d. 1 OR $.02; S d. 1-1½ OR $.27	RIVETING COST; AMPS 100 VOLTS 102	MINS 12	d. 1½ OR $.03	d. 2 OR $.04; S d. 1-6½ OR $.41; S d. 1-8¾ OR $.47	MINS 12	MINS 17	TONS 20 - NO MOVEMENT 40 - DITTO. 88 - RIVETS AND WELD SHEARED
JOGGLE LAP 2½" WIDE. SINGLE RUN OF WELDING AT JOGGLE, OTHER EDGE CAULKED. ⅝ RIVETS 4 IN NO. 9 APART. FIG. 13. HORIZONTAL WELD. 20 LBS.	d. 3¼ OR $.06; d. 2 OR $.04	d. 1¾ OR $.04; d. 11 OR $.22	RIVETING COST; AMPS 135 VOLTS 91	MINS 6	d. 1 OR $.02	d. 5 OR $.10; S d. 1-2 OR $.28; S d. 1-7 OR $.38	MINS 6	MINS 6½	LOAD GRADUALLY APPLIED UP TO 40 TONS NO MOVEMENT. 50 TONS - JOGGLE STRAIGHTENING 60 TONS - DITTO. 69 TONS - WELD BROKE AND RIVETS SHEARED.
LAP 2½" WIDE. SINGLE RUN OF WELDING ON ONE EDGE AND OTHER EDGE CAULKED. ⅝ RIVETS 4 IN NO. 9 CT. SPACING. FIG. 14. LIGHT WELD (VERTICAL) ① (FLAT) ② 20 LBS. CAULK	① VERTICAL d. 8½ OR $.17; d. 4 OR $.08	d. 3½ OR $.07; d. 9½ OR $.19	RIVETING COST; AMPS 95 VOLTS 100	MINS 8½	d. 1 OR $.02	S d. 1-0 OR $.24; S d. 1-2½ OR $.29; S d. 2-3½ OR $.33	MINS 8½	MINS 12	LOAD GRADUALLY APPLIED UP TO 50 TONS -NO MOVEMENT. 66 TONS - WELD BROKE AND RIVETS SHEARED.
VERTICAL WELD NO. 10 ELECTRODES FLAT WELD NO. 8 ELECTRODES SPECIMEN SIMILAR TO FIG. 8.	② FLAT d. 8½ OR $.17; d. 2¼ OR $.05	d. 3½ OR $.07; d. 11 OR $.22	RIVETING COST; AMPS 115 VOLTS 95	MINS 6¾	d. 1 OR $.02	S d. 1-0 OR $.24; S d. 1-2¾ OR $.29; S d. 2-2¾ OR $.33	MINS 6¾	MINS 6¾	LOAD GRADUALLY APPLIED UP TO 50 TONS -NO MOVEMENT. 103 TONS - WELD BROKE AND RIVETS SHEARED.
LAP 4" WIDE WELDED VERTICALLY BOTH EDGES TO BE PULLED AGAINST LAP 4" WIDE WITH 1⅛ RIVETS 3½ CTS. FIG. 15. VERT. WELD. ALL 40 LBS. PLATING	d. 9 OR $.18; S d. 1-7 OR $.38	d. 8½ OR $.16; S d. 5-7½ OR $.137	RIVETING COST; AMPS 115 VOLTS 96	MINS 57	d. 7¼ OR $.15	S d. 1-5½ OR $.35; S d. 7-9¾ OR $1.48	MINS 57	MINS 60	TONS 20 - NO MOVEMENT 30 - CAULKING VISIBLE 35 - SLIP 9/1000 INS. 50 - SLIP ⅛ IN. 65 - BREAK RIVETS SHEARED

ELECTRIC WELDING TESTS – QUASI-ARC METHOD.

BUTT JOINTS – DIAGRAMS 5/8" TO 1 FT.

STATEMENT OF COST AND TESTS APPLIED. SHEET.3.

NOTE:- TONS ARE FIGURED AS LONG TON OF 2,200 POUNDS.

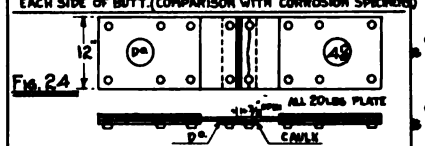
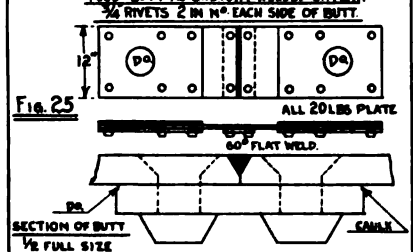
SKETCH AND DESCRIPTION	LABOUR	MATERIAL	POWER: CURRENT	POWER: TIME	POWER: COST	TOTAL COST	ACTUAL WELDING TIME	TOTAL TIME	RESULT OF TEST
ORDINARY SINGLE RIVETED BUTT. 3/4" RIVETS. FIG. 16. 12" – 12" ALL 20 LBS PLATE	s d 1-5½ OR $0.35	s d 1-6½ OR $0.38 COST OF RIVETS AND STRAP				s d 3-0 OR $0.73			TONS 5 NO MOVEMENT 10 CAULK AT A JUST VISIBLE 15 PITTO 20 CAULK AT A OPEN 5/1000 25 " " " " 20/1000 AND B STARTED 30 CAULK AT A OPEN 37/1000 AND B OPEN SLIGHTLY 30 RIVETS SHEARED AT ONE END OF BUTT.
ORDINARY DOUBLE RIVETED BUTT. 3/4 RIVETS. FIG. 17. 12" – 12" ALL 20 LBS PLATE	s d 2-3½ OR $0.56	s d 2-11 OR $0.71 COST OF RIVETS AND STRAP				s d 5-2½ OR $1.27			TONS 10 CAULK AT A JUST VISIBLE 15 " " A MORE VISIBLE 20 " " A OPEN 5/1000 25 " " A OPEN RIGHT ALONG 30 " " A OPEN 20/1000 35 " " A PITTO 40 " " A OPEN 1/16 AND B STARTED 50 CAULK AT A OPEN 1/8 & B OPEN 1/16 57 BREAK - RIVETS CP. SHEARED.
ORDINARY TREBLE RIVETED BUTT. – HAND RIVETED FIG. 18 12" – 12" 20 LBS. 3/4 RIVETS 25 LBS. STRAP	s d 2-8 OR $0.68	s d 4-4½ OR $1.16 COST OF RIVETS AND STRAP				s d 7-0½ OR $1.91			TONS 20 CAULK AT A VISIBLE 30 " " A OPEN 11/1000 40 " " A OPEN 17/1000 50 " " A OPEN 44/1000 AND B STARTED LOAD RELEASED CAULK AT A CLOSED TO 29/1000 60 TONS CAULK A OPEN 1/32 109 TONS BREAK. PLATE BROKE THRO' "X" CAULK A OPEN 11/32 CAULK B OPEN 3/16
ORDINARY TREBLE RIVETED BUTT. HYDRAULIC RIVETED FIG. 19. 12" – 12" 20 LBS. 3/4 RIVETS DOUBLE 25 LBS STRAP	s d 1-7½ OR $0.38	s d 4-10 OR $1.18 COST OF RIVETS AND STRAP				s d 6-5½ OR $1.57			TONS 20 CAULK AT A VISIBLE 30 " " A OPEN 7/1000 40 " " A OPEN 37/1000 50 " " A OPEN 7/16 60 " " A OPEN 9/32 110 BREAK. PLATE BROKE AS SHOWN.
PLAIN BUTT 60° BEVEL WELDED ON FLAT. FIG. 20. 8" – 8" ALL 20 LBS PLATE	d 11 OR $0.22	s d 2-7½ OR $0.64	AMPS. 100 VOLTS 96	MINS. 27½	d 2¾ OR $0.06	s d 3-9½ OR $0.82	MINS. 27½	MINS. 34½	LOAD GRADUALLY APPLIED WELD BROKE WITH LOAD 113 TONS
STRAPPED BUTT:- BUTT WELDED VERTICALLY, STRAP CAULKED ON EDGES. 3/4 RIVETS 4 IN NO. EACH SIDE OF BUTT FIG. 21. 7" – 7" CAULK	d 4 OR $0.18	s d 1-6½ OR $0.38 COST OF RIVETS AND STRAP	AMPS. 125 VOLTS 100	MINS. 45	d 6½ OR $0.13	s d 2-3½ OR $0.56 s d 7-4 OR $1.78	MINS 45	MINS. 47	LOAD GRADUALLY APPLIED 60 TONS NO MOVEMENT 118 TONS PLATE BROKE THRO' LINE OF RIVETS A
	s d 1-3 OR $0.30	s d 5-5½ OR $1.35				s d 9-7½ OR $2.34			
STRAPPED BUTT:- BUTT WELDED VERTICALLY, STRAP CAULKED ON EDGES. 3/4 RIVETS 2 IN NO. EACH SIDE OF BUTT FIG. 22. 7" – 7" CAULK.	d 5 OR $0.10	s d 1-3 OR $0.30 COST OF RIVETS AND STRAP	AMPS. 140 VOLTS 100	MINS. 37	d 6 OR $0.12	s d 1-8 OR $0.40 s d 6-4½ OR $1.35	MINS 37	MINS 38	LOAD GRADUALLY APPLIED 70 TONS NO MOVEMENT 117 TONS PLATE TORE FOR 4" OF WIDTH AND WELD FOR 6" IT IS NOT KNOWN WHETHER PLATE OR WELD GAVE THE FIRST.
	s d 1-0 OR $0.24	s d 4-10½ OR $1.19				s d 8-0½ OR $1.95			
ORDINARY TREBLE RIVETED BUTT. WITH 1/2" ANNERLED STRIP 4½" WIDE (SLIGHTLY DISHED) WELDED IN POSITION SHOWN FIG. 23. 12" – 12" 20 LBS. 3/4 RIVETS 25 LBS. STRAP.	s d 2-8 OR $0.65	s d 4-4½ OR $1.16 COST OF RIVETS AND STRAP				s d 7-8½ OR $1.81			TONS 40 NO MOVEMENT 50 BUTT CAULK JUST VISIBLE 60 " " OPEN 11/1000 70 " " " 44/1000 80 " " " 46/1000 90 " " " 3/32 SPECIMEN LEFT INTACT.
	d 4½ OR $0.09	s d 1-2½ OR $0.24	AMPS. 85 VOLTS 102	MINS. 14½	d 1½ OR $0.03	s d 1-8½ OR $0.41	MINS. 14½	MINS 14½	

ELECTRIC WELDING TESTS - QUASI-ARC METHOD

BUTT JOINTS - DIAGRAMS 5/8" TO 1 FT.

STATEMENT OF COST AND TESTS APPLIED. SHEET. 3.A.

NOTE;- TONS ARE FIGURED AS A LONG TON OF 2,200 LBS.

SKETCH AND DESCRIPTION	LABOUR	MATERIAL	POWER: CURRENT	POWER: TIME	POWER: COST	TOTAL COST	ACTUAL WELDING TIME	TOTAL TIME	RESULT OF TEST.
STRAPPED BUTT;- BUTT WELDED ON FLAT. 3/4 RIVETS 2 in ⅛ EACH SIDE OF BUTT. (COMPARISON WITH CORROSION SPECIMEN)  FIG. 24	£ s d .10 OR .18	COST OF RIVETS & STRAP £ s d 1-3 OR .30 £ s d 3-4½ OR .82	AMPS. 185 VOLTS 98	MINS. 20	d 3½ OR .07	£ s d 1-8 OR .40 £ s d 4-5 OR 1.07 £ s d 5-1 OR 1.47	MINS. 20	MINS 28	20 TONS NO MOVEMENT. 60 TONS DITTO 116 TONS BREAK. THRO LINE OF RIVETS.
VEED BUTT AS SKETCH. WELDED ON FLAT. ⅞ RIVETS 2 IN Nº. EACH SIDE OF BUTT.  FIG. 25	£ s d .10 OR .08	COST OF RIVETS & STRAP £ s d 1-3 OR .30 d 9⅛ OR .19	AMPS 105 VOLTS 97	MINS 6	d 3½ OR .01	£ s d 1-8 OR .40 £ s d 1-1½ OR .28 £ s d 2-9½ OR .68	MINS 6	MINS 11	20 TONS NO MOVEMENT 69 TONS WELD BROKE AND RIVETS SHEARED

ELECTRIC WELDING TESTS - QUASI-ARC METHOD

RIGHT ANGLED PLATE CONNECTIONS. - DIAGRAMS 5/8" TO 1 FT.

STATEMENT OF COST AND TESTS APPLIED

SHEET. 4.

NOTE;- TONS ARE FIGURED AS A LONG TON OF 2,200 POUNDS.

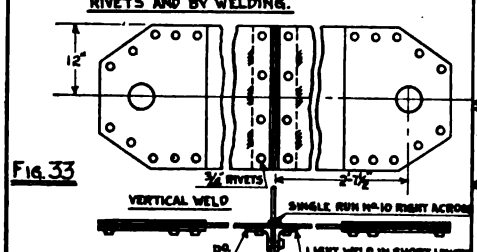
SKETCH AND DESCRIPTION.	LABOUR	MATERIAL	POWER TIME	POWER COST	TOTAL COST	ACTUAL TIME	TOTAL TIME	RESULT OF TEST.
FIG. 26 — 20 LBS. PLATING. 3½"×3½"×½" ANGLES WITH ⅜" RIVETS WT. SPACING. TEST PIECE 12" DEEP. 2 PLATES 6" WIDE CONNECTED TO CENTER PLATE 12½" WIDE	9 d. 1-N or $0.47	5 d. 3-4½ or $0.82 COST OF ANGLES AND RIVETS			5 d. 5-3½ or $1.29			LOAD / DEFLECT.: 5 TONS 1/32; 8 TONS 3/16; 8 TONS MAXIMUM LOAD
FIG. 27 — ACTUAL FILLET FULL SIZE. 20 LBS. PLATING 2 PLATES 6" WIDE CONNECTED BY HEAVY FILLET TO CENTER PLATE 12½" WIDE. VERTICAL WELD	5 d. 2-5 or $0.54	5 d. 11-2 or $2.71	AMPS. 105 VOLTS 85	MINS. 80	d. 9½ or $0.19	5 d. 44-4½ or $3.44	MINS. 80	MINS. 93	LOAD / DEFLECT.: 6 TONS 1/16; 7 TONS 1/8; 8 TONS 5/16; 9 TONS 7/16. 9.04 TONS MAXIMUM LOAD WELDING INTACT
FIG. 28 — ACTUAL FILLET FULL SIZE. 20 LBS. PLATING 2 PLATES 6" WIDE CONNECTED BY LIGHT FILLET TO CENTER PLATE 12½" WIDE. VERTICAL WELD	5 d. 1-0 or $0.24	5 d. 4-6½ or $1.10	AMPS. 110 VOLTS 90	MINS. 34	d. 4½ or $0.09	5 d. 5-10½ or $1.43	MINS. 34	MINS. 39½	LOAD / DEFLECT.: 2 TONS 1/16; 3 TONS 1/8; 4 TONS 3/16; 5 TONS 1/4; 6 TONS 5/16; 7 TONS 3/8; 8 TONS 7/16; 9 TONS 1/2. 9 TONS MAXIMUM LOAD WELDING INTACT
TENSILE TESTS								
TWO PLATES CONNECTED TO CENTRE PLATE. (ANGLES 3-RIVETS) — FIG. 29 — 20 LBS PLATING — TEST PIECES 2 IN NO. ① 3/4" RIVETS COUNTERSUNK ② 3/4" RIVETS NOT COUNTERSUNK	TEST PIECE ① 5 d. 5-7 or $0.87	COST OF ANGLES & 3 RIVETS 5 d. 6-6 or $1.98				5 d. 10-1 or $2.45			LOAD / DEFLECT. IN ANGLE / DEFLECT. IN RIVETS: 15 TONS 1/1000" / 40/1000"; 20 " 24/1000" 1/8"; 30 " 1/8 FULL 1/8". 30 TONS RIVETS PULLED THRO' ANGLE
	TEST PIECE ② 5 d. 5-6 or $0.86	5 d. 6-6 or $1.98				5 d. 10-0 or $2.43			LOAD / DEFLECT. IN ANGLE / DEFLECT. IN RIVETS: 35 TONS 3/1000" / 30/1000"; 40 " 5/16" 5/16". 40 TONS POINTS OF RIVETS SHEARED
TWO PLATES CONNECTED TO CENTRE PLATE. (VERTICAL WELD) — FIG. 30 — TEST PIECES 2 IN ① WITH HEAVY FILLET ② WITH LIGHT FILLET	TEST PIECE ① 5 d. 11-1 or $2.30	£ s d. 1-19-9 or $4.67	AMPS. 110 VOLTS 100	MINS. 335	s d. 4-2 or $1.01	£ s d. 2-15-0 or $13.36	MINS. 335	MINS. 412	NO MOVEMENT OBSERVED IN WELDING PLATE BROKE THRO' LINE OF RIVETS @ LOAD 209 TONS
	TEST PIECE ② 5 d. 4-0½ or $0.98	5 d. 12-1 or $2.44	AMPS. 120 VOLTS 92	MINS. 138	s d. 1-5½ or $0.36	£ s d. 17-7 or $4.28	MINS. 138	MINS. 188	WELDING FRACTURED CAUSING SEPARATION LOAD 186 TONS.
TWO FLANGED PLATES CONNECTED TO A CENTER PLATE BY WELDING AND 2 IN NO ⅝" RIVETS — FIG. 31 — BEND ⅞" BAR — VERTICAL WELD — pd	d. 2 or $0.04	d. 1¾ or $0.04	RIVETING COST			d. 2¾ or $0.06			WELD SHOWED NO MOVEMENT PLATE BROKE THRO' A WITH LOAD 125 TONS
	5 d. 2-2 or $0.77	5 d. 13-5½ or $3.24	AMPS. 120 VOLTS 108	MINS. 106	5 d. 1-3½ or $0.31	5 d. 17-9¼ or 5 d. 18-1 or $4.40	MINS. 106	MINS. 120	
TWO PLATES CONNECTED TO A CENTER PLATE BY ANGLES, RIVETS AND WELDING. — FIG. 32 — VERTICAL WELD — pd — HEAVY WELD ALL 20 LBS PLATING — WELDING IN 3" LENGTH NOTCHES WELDED — ANGLES 3½"×3½"×½"	d. 0 or $0.12	5 d. 5-4 or $1.30 ANGLES AND RIVETS				5 d. 5-10 or $1.42			WELD BROKE AT ROOT OF ANGLE AND AT NOTCHES IN FLANGE LOAD 56 TONS.
	5 d. 17-0 or $1.82	£ s d. 1-17-9 or $4.14	AMPS. 110 VOLTS 115	MINS. 286	5 d. 2-11 or $0.71	£ s d. 2-8-2 or $11.72 £ s d. 2-14-0 or $13.14	MINS. 286	MINS. 280	

ELECTRIC WELDING TESTS - QUASI-ARC METHOD.

RIGHT ANGLED PLATE CONNECTION - DIAGRAMS 5/8" TO 1FT.

STATEMENT OF COST AND TESTS APPLIED. SHEET. 4.A.

NOTE; TONS ARE FIGURED AS A LONG TON OF 2,200 LBS.

SKETCH AND DESCRIPTION	LABOR	MATERIAL	POWER: CURRENT	POWER: TYPE	POWER: COST	TOTAL COST	ACTUAL WELDING TIME	TOTAL TIME	RESULT OF TEST.
TWO PLATES CONNECTED TO ONE CENTRE PLATE BY RIVETS AND BY WELDING.  FIG. 33	5 d 1-3 or $ .30 5 d 1-10½ or $ .46	ANGLES & RIVETS 5 d 5-10½ or $1.43 5 d 5-9½ or $1.41	AMPS. 90 VOLTS 106	MINS. 58	d 6½ or $ .13	5 d 7-1½ or $1.73 5 d 8-2½ or $2.00 5 d 15-4 or $3.73	MINS 58	MINS. 72	20 TONS NO MOVEMENT. 40 TONS DITTO 60 TONS DITTO 74 TONS WELD AT ROOT OF ANGLE BROKE.

Section D—Application To New Construction

With reference to the application of the process to New Construction a conference was held on the 25th of October, 1917, Officers attending from Davonport, Chatham and Pembroke Yards and a report on the conclusions arrived at is now in circulation to these Yards for concurrence. The recommendations made and agreed to at the conference were as follows:

It was agreed that whilst Quasi-Arc process could not be advantageously adopted in all cases as a substitute for the present process of drilling, riveting, caulking, etc., yet its use would undoubtedly result in a great reduction in the amount of labor involved in such processes.

It should be observed generally, that in the process of framing a ship it is necessary to provide means by which the various parts can be temporarily attached to each other and held securely in position before the work of permanently securing such parts is proceeded with.

With regard to non-watertight work it was agreed that the present arrangement of laps, butts, stiffeners, etc., should be retained, and that, as the spacing of holes in such work for riveting is the maximum consistent with the proper closing of the work and general practice has shown that it is sufficient for this purpose, it was not considered that any advantage would accrue for the application of the Quasi-Arc process to such work.

With the watertight work, however, the case is quite different, the present practice involving a much larger number of rivets than in non-watertight work, and it was agreed that all work of this nature could probably be well and efficiently performed with economy in labor by increasing the rivet spacing as much as possible consistent with the proper closing of the work and supplementing this by Quasi-Arc welding so far as it is necessary to meet the requirements for strength and watertightness.

In addition to this it was agreed that the process of water testing would also be greatly facilitated, with a corresponding saving in time and labor by the adoption of this practice.

It was considered, however, that the development of the process would necessarily be gradual and would depend on the results of experience in work at the ship on a much larger scale than the experiments already carried out.

The adoption of the proposals to the extent recommended would, however, afford a very large field for experience, and the more general application to non-watertight work could be reconsidered at a later date if justified by such experience.

It was suggested by Mr. Hockaday, Constructive Manager, Davonport, and generally considered desirable, that the tests already carried out should be supplemented by vibration tests and it is proposed to carry out such tests, if satisfactory means can be devised in the course of the experiments. The question of corrosion also arose, but a separate set of tests are being carried out with the object of determining the effect, if any, of corrosion, and results will be reported in due course.

It will be observed that the points raised are of a general nature as it was impracticable to discuss details as to the means of application, etc.

The following additional remarks are therefore offered, in which the question is dealt with in greater detail and definite recommendations made as to the means of applying the process.

Further tests have also been carried out since the date of the conference and the results of these are also included.

The question of the relative costs of welding and riveting was not discussed at the conference, but in comparing the tests shown on the sheets it should be observed that no allowance has been made for any work which may have to be performed after the joints are completed, the costs of the riveted joints being estimated on piece-work prices and simply representing the cost of making the different joints.

Taking subsequent work, such as water testing, injecting, recaulking, etc., into consideration there is little doubt that the cost of riveted work would be increased to a greater extent than that of welded work.

In addition, it has been established that a welded joint once completed would remain watertight up to the breaking point of the joint which is not the case with a riveted joint. Much of the trouble now experienced with leaky oil tanks, etc., due to straining of the ship would therefore almost certainly be avoided by the adoption of this process.

Further advantages would be the appreciable saving in weight which would result, and with the wider spacing of rivets which would be used at watertight frames and bulkheads, the section of the ship at such places would be weakened to a much less extent than at present, and compensation liners would not be necessary.

It is difficult to estimate the saving of time which would be effected from the results of experiments on such samples, but a comparison of the cost of labor on riveted and welded samples shows that the total amount of labor expended on a lap such as Fig. 10 is less than that on a double-riveted lap,

although the strength is slightly greater. Similarly the cost of labor on a butt such as Figs. 23 and 24 is only about one-half that on a treble-riveted butt, while again, the strength is greater. Thus while the total time taken in completing one welded joint may be greater than that taken for a riveted joint, one man would be performing the work formerly performed by several, and the saving in the number of men required to do a number of joints in the same time would probably be considerable.

Against these many advantages must be set certain disadvantages, which could, however, probably be eliminated as a result of experience. For instance, the proper supervision of the work would undoubtedly be difficult since, in joints which require the application of two or more layers or "runs" of welding, the outward appearance of the finished work might be quite satisfactory, whereas the joint might contain patches or even layers of slag. It would, therefore, be necessary to institute such a scheme of supervision as to ensure that the slag which covers each successive run of welding had been entirely removed before another run was started, since the presence of this material in any quantity would seriously affect the quality of the weld.

Another, and a serious objection, is the impossibility of other men working within the range of the arc, but this could be overcome in most cases by the provision of portable screens surrounding each operator.

Further, the question arises as to the methods of dealing with repairs to damaged plates which have been welded together, but by the use of oxy-acetylene burning plant, chipping hammers, etc., and a slight rearrangement of laps and butts, this difficulty could probably be overcome.

It was also found, in welding the test pieces, that fairly considerable distortion occurred during welding due to the contraction of the welded metal, but this was not nearly so marked with laps as with butts. This was prevented by clamping angle bars to the back of the pieces during welding, but it does not necessarily follow that this would occur in practice, as both the plates to be welded together would be securely attached to the frames or other structure before welding. This, again, is a matter which only experience at the ship can definitely settle, but even if such distortion did occur, it should not be a difficult matter to counteract it.

Another result of the contraction of the welded metal was to draw the edges of a butt together. This was noticed in several test pieces, more particularly when using 40-lb. plate.

Thus, in welding a V butt, the tendency was for the plate at the parts remote from the weld to close. This was scarcely noticeable with 20- and 25-lb. plating, but with 40-lb. plate, the apex of the V closed up on several occasions and had to

be burnt through by the use of a higher current before starting to weld at that place. There is a possibility that this might assume much larger proportions when applied to a butt 5 feet or 6 feet in length, but it is not anticipated that the effect will be very marked with 20-lb. plating especially as the plates would be securely attached to frames, etc. This is also a matter for trial at the ship.

With regard to the means of applying the process, and the types of joints considered to be most suitable for ship work, the joints shown in Sheet 1, 1A, and 1B, could not be applied without certain modifications. Thus in the case of the V welds it would be necessary for some provision to be made for connecting the plates together before welding, and the use of such a joint will be discussed when dealing with butts. With regard to the other type of joint on Sheet 1, the costs are so high due to the strip being welded at the edges that it is out of the question to consider its adoption, but a joint in which the welding is omitted has been tried and will be referred to later.

With regard to the lap joints shown on Sheets 2 and 2A, it is considered that the type of joint shown in Fig. 10 could be used extensively in place of double-riveted laps, such as in outer and inner bottom plating, bulkheads, etc., and also in many cases where a flush surface is not essential, could be used in place of double-riveted butts. Where a specially high strength is required the weld could be increased in thickness to that used in Fig. 10, although this would practically double the cost, but even then the cost is comparable with that of a treble-riveted butt.

The joint in Fig. 10 possesses a particular advantage, apart from cost, since only one run of welding being applied to each edge the possibility of slag being left in the weld is considerably less than in the case of joints requiring more than one run. In this case, therefore, the appearance of the finished weld would be very good evidence of the general quality of the work, and the difficulty of proper supervision previously referred to would be greatly diminished. This particular joint was welded vertically, which is the simplest and most economical method of welding a lap, and the price for such a joint welded horizontally as in side plating, bulkheads, etc., and flat, as in flats and decks, would probably be greater on account of the overhead welding which would be involved.

It would, therefore, be desirable in cases where the strength is sufficient, to limit the amount of overhead welding by the introduction of an intermittent run as Figs. 11 and 12. The price is thus reduced and the strength is not greatly affected and it could always be arranged for the most awkward weld to be made intermittent, the more accessible edge being given a continuous run.

The adoption of laps with a single or double run of welding along one edge only, and no welding on the other edge, cannot be recommended for extensive use in view of the comparatively low results obtained in 4 of the 6 samples tested. For unimportant watertight work, however, where single-riveted laps are now used, these are considered to be a great improvement on a single-riveted lap, and for such work the lap in Fig. 9 is the most suitable on account of its low cost and little inferiority in strength to those in Figs. 6 and 7.

In using such a joint, however, it would be inadvisable to space the rivets more widely apart than about 8 diameters as otherwise considerable corrosion might be set up between the plates on the unwelded side which might in time have the effect of forcing the plates apart and even breaking the rivets.

In any case, whichever system is applied to outer bottom plating, a continuous run should be made on the outside edge, so that any leaks developing during water test could be readily detected, and also in order to render the outer surface as smooth as possible.

As regards the flat bottom, therefore, it is not seen how a continuous row of overhead welding on one edge of each lap can be avoided no matter what the system of plating may be.

With regard to side plating, however, if it were decided to adopt laps with a continuous run on the outside and an intermittent run on the inside it would be advantageous to adopt the "clinker" system of construction, the plates overlapping upwards, since this would reduce the amount of overhead welding to a minimum.

In cases where a flush surface is necessary and laps cannot be adopted the selection of a suitable joint lies between those shown in Figs. 20, 22 and 25.

The only modification which would be necessary to the joint in Fig. 20 would be the provision of a butt strap as in Fig. 25, and it is not anticipated that this would have any appreciable effect on the strength of the weld.

The welding cost of the joint in Fig. 20 is seen to be very low as compared with Fig. 22, but this is accounted for by the fact that the former was welded on the flat and the latter vertically.

Comparing Fig. 20 with Fig. 24, which is a repeat of the rough-sheared butt with flat welding, it is observed that there is little difference in the cost of welding.

As the strength of the two types of joint is practically identical, so far as the welding cost is concerned, it appears to be immaterial which type is adopted for positions in which flat welding can be done and judging from the results on Sheet 1, the same would probably apply to vertical welding.

The butt, in Fig. 22, however, has the advantage that no planing is necessary and accurate fitting of the butt is not required. The distance between the ends of the plates should not be less than ⅜" as otherwise difficulty would be experienced in efficiently welding at the bottom of the groove, but the butt could always be opened to this amount by chipping in place. On the other hand, it would be immaterial from a strength point of view if this distance were exceeded, but on account of the greater expenditure in electrodes which would be involved it should be kept as near ⅜ as possible. This type of butt would therefore be more simple to fit at the ship than a V butt, and as the cost of welding is about the same, it is considered that, in cases where the welding can be done either vertically or flat, and where strength is required in conjunction with a flush surface this butt is on the whole the most suitable for adoption.

The objection to welding such a joint horizontally has already been referred to, but the results on Sheet 1 show that the same objection does not apply to V butts. If, therefore, a butt of this strength were required in such a position that the welding had to be done horizontally, it would be preferable to use a Veed butt with a strap and widely spaced rivet. Such a requirement would rarely, if ever, occur in shipbuilding, except in connecting double thickness in a vertical plane.

It should be observed that neither of these butts would be suitable as a substitute for a riveted lap or a single riveted butt on account of their high cost, and for a purpose where a flush surface is required and strength is not such an important consideration the butt in Fig. 25 would probably be the best substitute, its strength being superior to that of a single-riveted butt and its cost about the same.

It has already been seen that the strength of a butt Veed through the whole thickness is 113 tons, and by varying the depth of the V it would therefore be possible to obtain a butt of any strength up to this limit.

It is not considered that any of these butts could be sufficiently welded overhead, and even if an efficient joint could be obtained the cost would be excessive.

For the butts in the flat portion of the outer bottom, therefore, the most satisfactory joint would be obtained by placing the butt straps on the outside and welding from inside, but if the rivets were widely spaced it would still be necessary to weld the edges of the strap lightly from underneath to prevent free access of water between the strap and the plating, the rivet spacing not being suitable for caulking. This, however, could be avoided by placing the rivets at watertight spacing as in Fig. 21, as this would certainly be cheaper than overhead welding along the edges of the strap. If this system were adopted the edges of the strap could be

bevelled, leaving only sufficient of the square edge for caulking, so as to reduce the resistance to a minimum.

With regard to the application of the process to boundaries of watertight bulkheads, decks, frames, etc., the simplest method of erection of such structures is undoubtedly attained by the use of angle bars around the boundaries as at present.

Such joints as those in Figs. 26, 27, 28 and 30 are, therefore, considered to be impracticable for ship construction, and apart from this, their cost is excessive. The remark as to cost applies to the method adopted in Figs. 31 and 32.

For such work the cheapest method of applying the process is that illustrated in Fig. 32, in which the present method of construction is retained, excepting that the plates are brought into contact instead of leaving a caulking space, and the rivets are placed at non-watertight spacing. The necessary watertightness is given by a single run of welding at the junction of the plates, and additional lengths of a light weld on the flanges between the rivets. The strength of such a connection is superior to that of a riveted connection, but in cases where the boundary had curvature as in the connection of bulkheads to the ship's side it would be difficult to arrange for the plates to be in contact at all points. In such cases the plates should be brought together as closely as practicable, the space between being filled in as far as possible.

It would certainly not be satisfactory to adopt the alternative shown in Fig. X, since the cost would be excessive, three continuous runs being involved. Also the plate would not be connected at the edge A, and any bending effect would tend to open this edge on account of the wide spacing of the rivets. This type of connection is therefore not recommended.

It should be observed generally that in practice it would be preferable for the riveting to be done prior to welding in all types of joints as greater stiffness and resistance to distortion during the welding would be ensured.

It is pointed out that the whole of these proposals have been based on the results of experiments conducted on 20 lbs. and 25 lbs. mild steel plating, and the recommendations made are not intended to apply to plating over 25 lbs.

A few tests have been made on 40 lbs. plating both mild steel and H. T., the results being shown on Sheets 1 and 1-A.

The closing effect on the plates which was noticed during welding has already been referred to. In addition, when using 40 lbs. plate, it was found, in two cases, that owing to a portion of the joint having been completed and allowed to cool, on restarting the work the next day, cracks developed between the weld and the plate in one case, and in the weld in another case, the latter being an H. T. plate. It was stated by the representative of the Quasi-Arc Company that if this

occurred in practice, the cracked portion could be burnt out by the use of a higher current, and the work recommenced, but this would be a very costly process in comparison with the cost of riveted work. There appears to be little danger in this occurring, if the work once started is proceeded with continuously, so retaining the heat in the plates. Generally speaking, however, apart from this possibility, the results of the tests on 40-lbs. plate, so far as they have gone, are not so satisfactory as with 20 lbs. and 25 lbs. plating, before any definite recommendations are made for dealing with plating of this thickness further experience is necessary—in fact it would be desirable to repeat a number of tests both with riveted and welded butts using mild steel and H. T. steel, and, if approved, arrangements will be made for this to be done.

Report No. 12

DESCRIPTION OF SPOT-WELDED CAR

Mr. James Osborne's Spot-Welded Freight Car.

Mr. James Osborne, Chief Electrical Engineer of the American Car and Foundry Company, of St. Louis, has supplied me with the following particulars of a 50-ton gondola car in which the entire superstructure was welded, with the exception of the ladder irons.

In the first instance, Mr. Osborne made a tour of all the welding companies, who advised him that they could not build a machine which would be capable of doing such heavy work. It was therefore necessary for him to design and build a special machine which is referred to in the general description hereunder.

DESCRIPTION OF AN ELECTRIC SPOT-WELDED FREIGHT CAR

(Photographs on Pages 176-181.)

Previous to seven or eight years ago electric spot-welding as applied to railroad rolling stock construction had been applied only to the welding of plates of very small gauge for passenger cars, but in 1911 the American Car and Foundry Company, of St. Louis, Mo., designed a gondola freight car of fifty tons capacity, the superstructure of which was electric spot-welded.

Attempts were made to purchase a welding plant which would weld plates having a thickness of from one-quarter (¼) to three-quarters (¾) of an inch, but being unable to obtain suitable equipment in the open market, a special welder was designed and built, consisting of a welding transformer arranged with a 440-volt primary and having about 85 K. V. A. capacity. The secondary of this transformer consisted of a flexible copper lead of sufficient length to give a welding gap of sixty-six (66) inches. The transformer was placed at one end of a structural steel frame and the other end comprised the welding jaws.

The pressure was applied by means of a hand wheel, the transformer was provided with various primary combinations to obtain different voltages, and for further regulation a choke coil was used. Upon the completion of the construction of the welding machine it was tested and found entirely satisfactory.

It had been decided to spot-weld as much of the freight car as practical and, accordingly, the entire superstructure was welded in this manner except the iron ladder and other small parts, several of which are mentioned later.

Several notes of interest follow:

The bottom cover plates of the cross bearers and the entire cover plates on top of the members were spot welded. A few rivets were used to hold the hinge castings in place.

The bottom cover plate of the body bolster which carries the entire weight of the load of the car at each end was spot-welded to the flanges of the diaphragm. Three rivets were used to hold in place the cast iron side bearings.

After the car was finished in 1911, it was tested and several test trips were made. It was observed that this car unlike a riveted car, when a test load is applied, invariably settles, until the rivets obtain a solid bearing. This was not the case in the welded car, as it was perfectly stiff. The usual deflection was noticed upon loading, but upon removing the test load the car assumed its original position.

After being tested the car was turned over to the Burlington Road, by whom it was used exclusively for the coal trade.

In 1916, after the car had been in actual service for five years, it was sideswiped in a wreck. An obstruction passed between the top end of the strakes and the chord angle, which bent these members. All but one spot weld remained intact.

The car has been examined from time to time since it was built, and the welded joints have stood the severe strains of continuous hard use.

The car is still in service and is giving as good results as a riveted car.

Description of Photographs of Spot-Welded Gondola Coal Car.

Photographs 1, 1A and 1B show a general view of the welding machine. Note that the pressure was applied by means of a hand wheel. The transformer was provided with various primary combinations to obtain different voltages.

Photograph 2 shows the under frame of the car containing the cover plates over the center sill and cross bearers—the arrow points indicate that the bottom cover plates of the cross bearers were spot-welded.

Photograph 3 shows a view of the body bolster. This is the member which carries the entire load of the car at each end.

Note the bottom cover plate was spot-welded to the flange of the diaphragms. The three rivets shown are for the purpose of holding in place a cast iron side bearing.

Photograph 4 shows the welder in the act of welding the floor sheet to the body bolster.

Photograph 5 shows the welder fastening the end sheet to the floor sheet.

Photograph 6 shows the process of welding the top chord angle to the side sheets. Note the splice plates used in joining the side sheets. Where this splice plate is welded to the top chord angle it was necessary to weld through four thicknesses of metal as a side strake was used on the outside for a splice plate.

Photographs 7 and 14 show one of the main end sheets. The bath tub section stiffener across the center of the sheet was spot-welded in place as well as the top chord angle, as indicated by the arrows in photograph 7.

Photograph 8 shows one of the doors. Note that the wrought iron hinges were spot-welded as is also the "Z" and angle stiffeners. It was necessary, however, to rivet the corner castings.

Photographs 9 and 10 show other parts of the car in course of construction.

Photograph 11 shows a picture of the completed car.

Photograph 12 shows a picture of a similar car in the same lot which was riveted. By a careful comparison the number of rivets which were eliminated from the superstructure of this car may be readily noted.

Photograph 13 shows a view of the car made in 1916 after the car had been in actual service for five years.

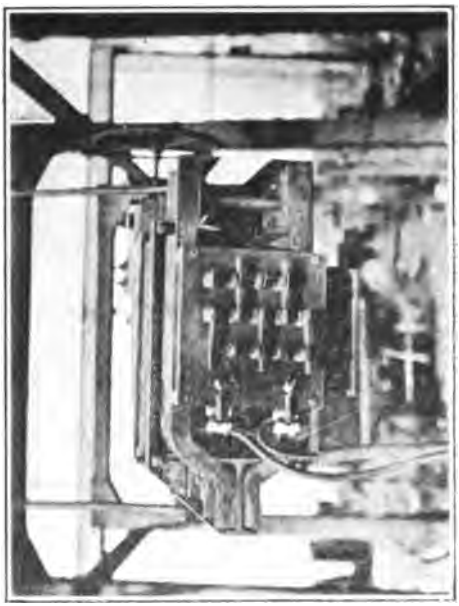


Fig 1a

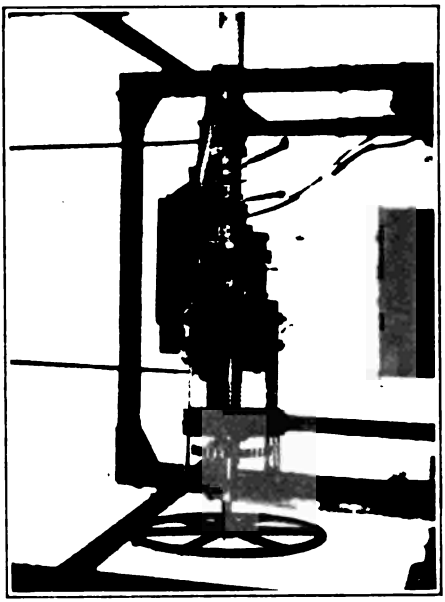


Fig. 1b

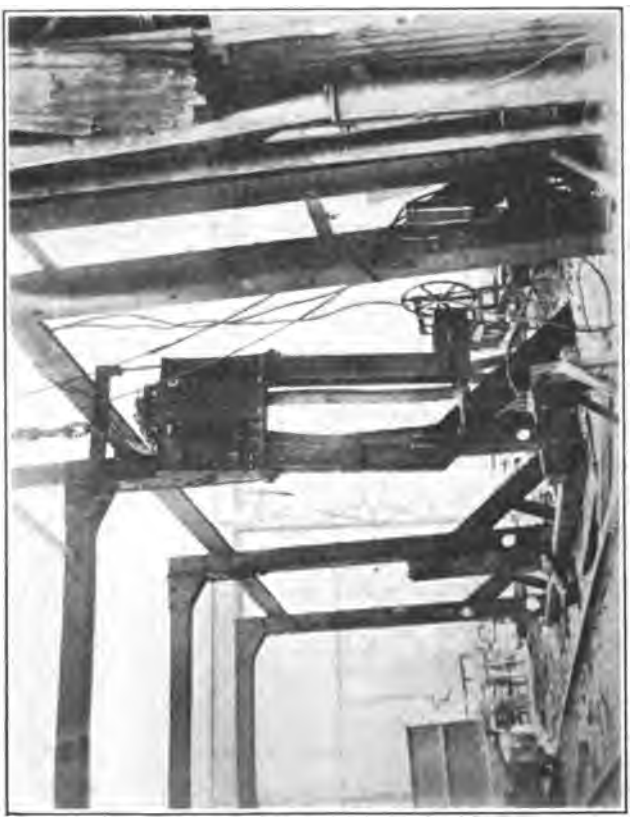


Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 7

Fig. 8

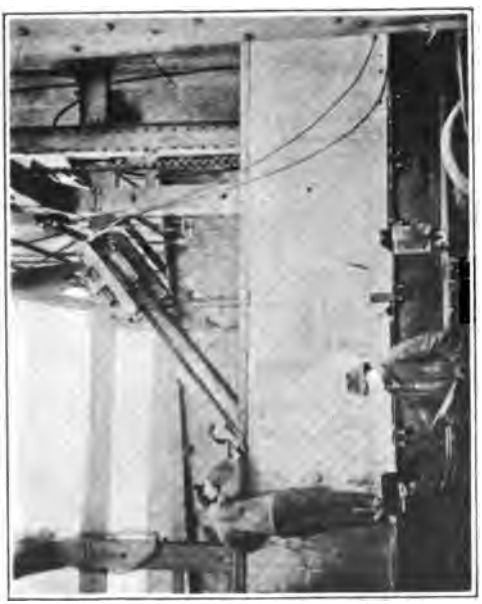


Fig. 6

Fig. 6a

Fig. 9

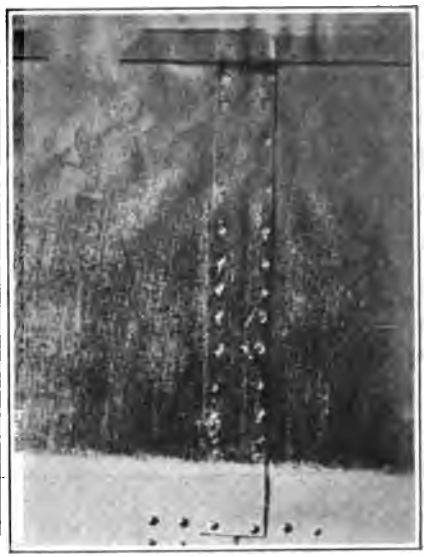


Fig. 10

Fig. 11

Fig. 12

Fig. 13

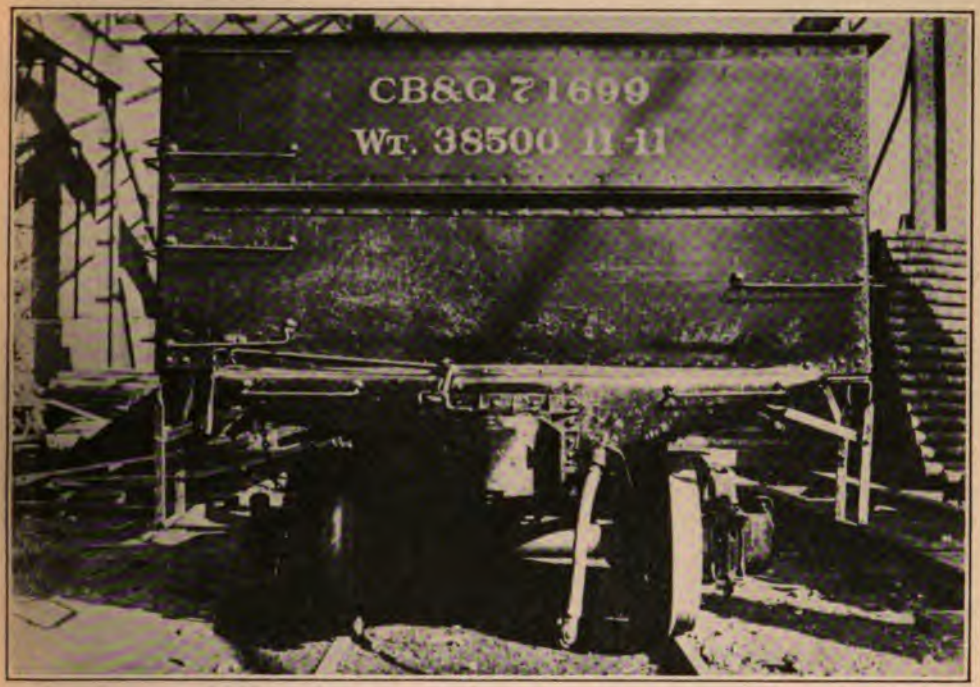


Fig. 14

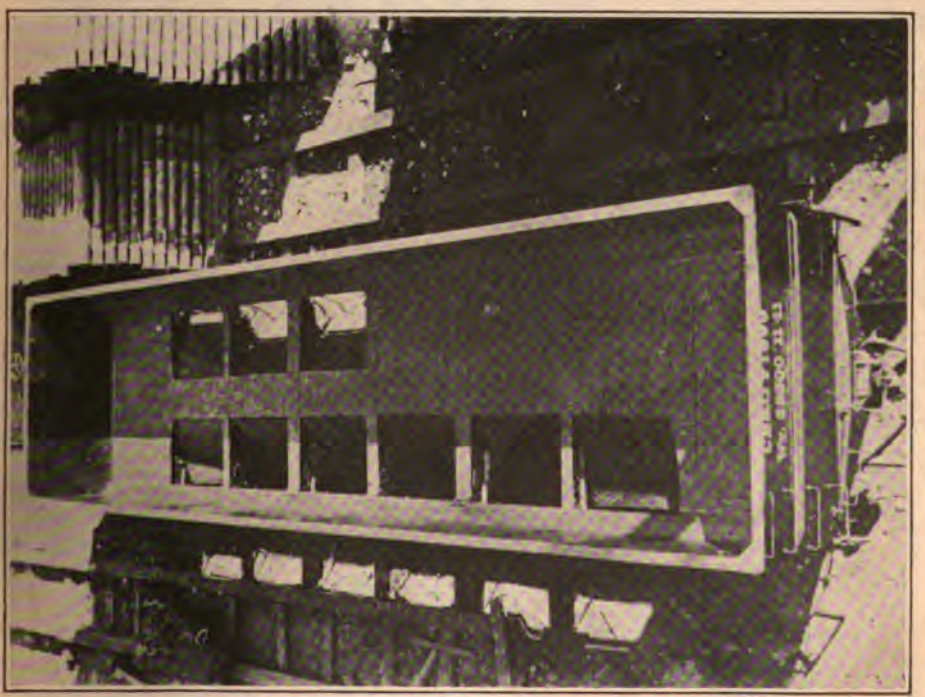


Fig. 15

Report No. 13

LIST OF SHIP PARTS FOR WHICH VARIOUS AUTHORITIES REQUIRE AND ALLOW ELECTRIC WELDING.

(A)—Recommendations by Lloyds and American Bureau
(B)—Allowed by British Admiralty
(C)—Allowed by U. S. Navy Department
(D)—Examples of Electric Welding Applications at British Admiralty Dockyards.
(E)—Sundry Applications of Electric Welding.

SECTION A

LIST OF SERVICES FOR ELECTRIC WELDING

Recommended by:

LLOYDS REGISTER OF SHIPPING AND
AMERICAN BUREAU OF SHIPPING
on 25th March, 1918.

Deck Rail Stanchions to Plating
Clips for Detachable Rail Stanchions
Continuous Railing Rods (Joints)
Attaching Deck Collars (L Rings) around Ventilators
" " " " " Smokestack
" Cape Rings, Smokestack, Pipes, etc.
" Galley Fixtures to Plating
" Bath and other Fixtures in Officers' Quarters
" Cowl Supporting Rings to Ventilators
Bulwark Top Splicing and End Fitting
Skylights over Galley
(a) Engine Room Stairs and Gratings
(b) Boiler Room " " "
Attaching (a) and (b) to Plating
Grab Rods on Casing
All Stairs and Ladders, including Rail Attachments
Door Frames to Casing, Hinges, Catches, Hold Coach-hooks, etc.
Clips for attaching Interior Wood Finish to Casing
Entire Screen Bulkhead
Coal Chutes
Butts of W. T. and O. T. Boundary Bars on Blkds., or floors in double bottom
Ventilator Cowls
Stacks and Uptakes
Bulkheads (that are not structural parts of the ship), partition bulkheads in accommodation
Framing and Supports for Engine and Boiler Room Flooring or Gratings
Cargo Batten Cleats
Tanks (that are not structural parts)
Shaft Alley Escapes
Steel Skylights over Accommodation Spaces

Engine Room Skylights
Grab Rods on exterior and interior of Deck Houses
Deck Houses not covering unprotected openings through weather decks
Reinforcing and Protecting Angles Round Manholes
Joints of W. T. Angle Collars at frames in way of W. T. Flats
Other parts of a vessel in which electric welding is proposed must be submitted for consideration.

SECTION B

LIST OF SERVICES FOR ELECTRIC WELDING

Allowed by:
BRITISH ADMIRALTY, NOVEMBER, 1917

Constructive Department

Ventilation Trunking where not less than $\frac{1}{16}$".

Reinforcing worn castings, forgings, etc.

Repairing fractures in castings, such as stems, stern posts, rudder frames, etc.

Attaching clamp for bow extensions.

Making steel masts and derricks.

Welding foundation bars for engine and boiler bearers, etc., to inner bottom to avoid piercing oil tanks.

Making and securing in place, storeroom, galley, mess and cabin fittings.

Making coamings, carlings, hatchways and skylights generally.

Welding around collars where frames, beams, etc., pass through W. T. Decks, bulkheads, etc.

Attaching flanges to pipes, pillars, etc.

Welding rungs in ladders.

Attaching brackets, eyeplates, etc., in connection with stowing and working of torpedoes, ammunition, etc.

Construction of tanks, bins, etc:

Attaching side plating to rudder and hydroplane castings.

Renewing ribs of chequered plating to avoid scrapping the plating.

Making right angled or other bends in angle bars, tee bars, etc. This is done by notching one flange, bending the angle so as to close the notch and welding along the junction.

Making good pitting in bottom plating.

Welding studs into armour for the attachment of fittings. (This has been carried out with satisfactory results on the "COMMONWEALTH" for attaching the frames and plating of bulges.)

Engineering Departments

General work for which oxy-acetylene has hitherto been accepted.

Making steel pipes not subject to steam, or for working

pressures not in excess of 50 lbs. per sq. in., e.g., bilge suction pipes, vent and blow pipes, etc.

Welding on flanges on low pressure pipes, limits for steam pipes 2½" dia. and 30 lbs. working pressure; limits as regards other pipes, below 3½", 100 lbs., above 3½", 50 lbs. working pressure.

Repairs to steel castings or forgings to reproduce jointing surfaces, wearing parts, etc., where requirements as regards strength and safety are not involved, e.g., reinforcing door joints of metal drums, building up damaged key ways, building up ends of shafts to fit enlarged holes in flywheels, etc.

SECTION C

LIST OF SERVICES FOR ELECTRIC WELDING

Allowed by:
UNITED STATES NAVY DEPARTMENT
SEPTEMBER, 1917.

Navy Department,
Bureau of Construction and Repair,
Washington, D. C.

In September, 1917, the Bureau authorized the use of electric welds in the following cases, subject to the approval of the Superintending Constructor in each particular case:

(A) Manufacture of angle staples
(B) Built up plate staples
(C) Recesses in form of pocket
(D) Drain wells
(E) Welding of plates to angles to increase the width of the same for attachment of fittings.
(F) Manufacture of small tanks (if not pressure tanks)
(G) Butts of hatch trunks
(H) Corners of flanged or dished plates
(I) Butts of angle rings
(J) Built up channels from angles and flat iron.

Tentative approval is also given to using electric welding in the following cases, subject to the approval of the Superintending Constructor in each particular case:

(a) Liners to shell, tank tops and bulkheads.
(b) Stiffening rings to plates for making up covers over openings.

The Bureau desires that particularly close inspection be made on all work involving welding as authorized herein.

SECTION D

EXAMPLES OF ELECTRIC WELDING APPLICATIONS AT BRITISH ADMIRALTY

List of Examples of Applications of Electric Welding at Admiralty Dockyards.

(a) Welding the plates of tanks, etc., pipe flanges and ventilating ducts.
(b) Making holes in armour plating to receive studs for securing bulges to armoured vessels. The studs are inserted in the holes and then welded into position. Some of these studs were tested to destruction without disturbing the weld.
(c) Welding manhole coamings to propeller shaft tubes.
(d) Fitting dished strips over riveted joints of hull plating to stop leakage at the riveted butt.
(e) Repairing fractures in cast steel stern posts and rudders, the fractures of which were reinforced by means of electric welding.
(f) Welding plates forming the auxiliary hull of cruisers where the stability had to be increased and protection provided against submarine attack.

METHOD ADOPTED BY THE BRITISH ADMIRALTY IN THE ELECTRIC WELDING OF WATER-TIGHT JOINTS FOR SHIP STRUCTURES AND OIL TANKS SUBJECT TO HEAVY STRESSES

The method adopted by the British Admiralty to make watertight joint in ship structures and oil tanks subjected to heavy stresses is described and illustrated hereunder:

Comparatively thin and flexible metal sheets are used (usually ⅛″), which will cover the joint lines, the sheets being welded to the plating to eliminate all risk of leakage. In preparing sheets for the purpose, rolled steel plates may be

used of a thin guage, for example, No. 12 guage; these sheets are annealed throughout in order that their consistency may be as uniform as possible after welding. They are laid over the joint lines and fillet-welded at their edges to the plates at each side of the joints.

The sketches clearly show the construction.

Figures 1 and 2 show riveted plating with comparatively narrow steel strips (a) laid over the joint lines and welded at each side at (b) where one strip meets another over a plate joint, the end of the abutting strip is welded to the edge of the outer strip or to the plating as at (c) Fig. 1. In this figure the applied strips (a) may be only from 1" to 2" broad so that they will be inside the lines of the rivets. The steel strips can be fed down against the surface of the plating as they are being welded as illustrated in Fig. 3, the ends of successive strips being welded where more than one length of strip is required for a joint line.

The resultant structure is absolutely watertight and will withstand very high stresses without showing any sign of leakage. The welded strips actually reinforce the joints, while with stresses large enough to open the joints somewhat, the thin annealed strips can extend or bend transversely to the extent required without their welded edges breaking away. Even with no caulking between the edges of the plates, it is an improvement over existing plating structures, as regards resistance to opening up of the joints and risk of leakage. The actual joint line may also be welded before the strip is applied as at (c) Fig. 2, when considered advisable.

The thin covering plates may also be applied so as to extend over the rivet heads if desired, which then renders the caulking of the rivets of less importance, or unnecessary; Fig. 4 shows in section a flat steel strip (a) which is wide enough to cover the rivet heads, applicable to cases where the rivet heads (f) are countersunk. The strip (a) need not necessarily lie flat against the plating, but may be buckled outwardly to allow freedom of expansion in a direction extending along the joint line, as in Fig. 5. If the rivet heads project, as in Fig. 6, the steel strips may be bent inwardly at their edges beyond the rivet lines and welded there. This also provides an element of flexibility. In such cases as those of Figs 5, 6 and 7, where the strips are curved and extend away from the plating surface over part of their width, the ends of the strips may either be flattened down to enable them to be welded to the plating or to crossing strips, or the crossing strips may have their edges lifted to apply them to the ends of the first mentioned strips, whichever is most convenient.

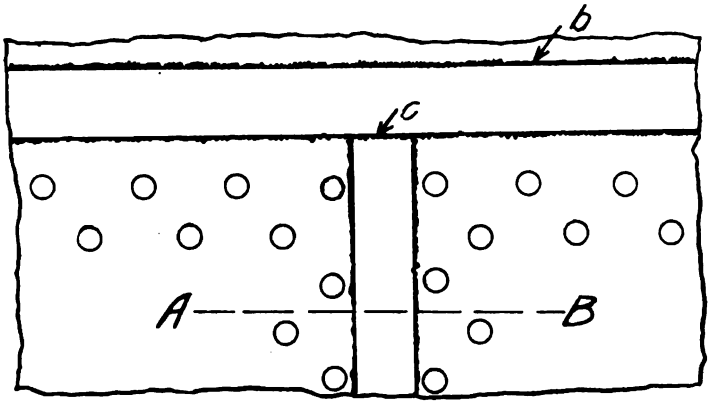


Fig. 1.

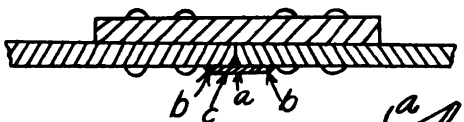


Fig. 2.

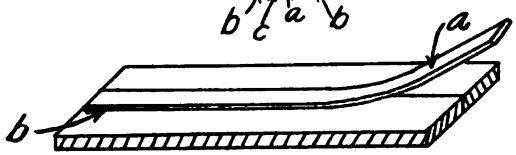


Fig. 3.

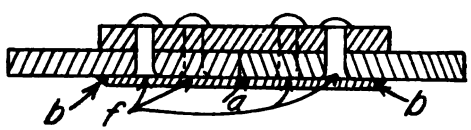


Fig. 4

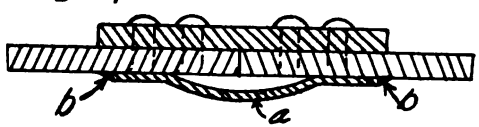


Fig. 5

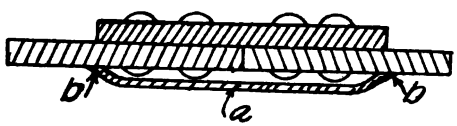


Fig. 6.

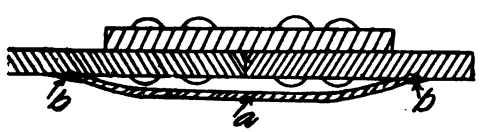


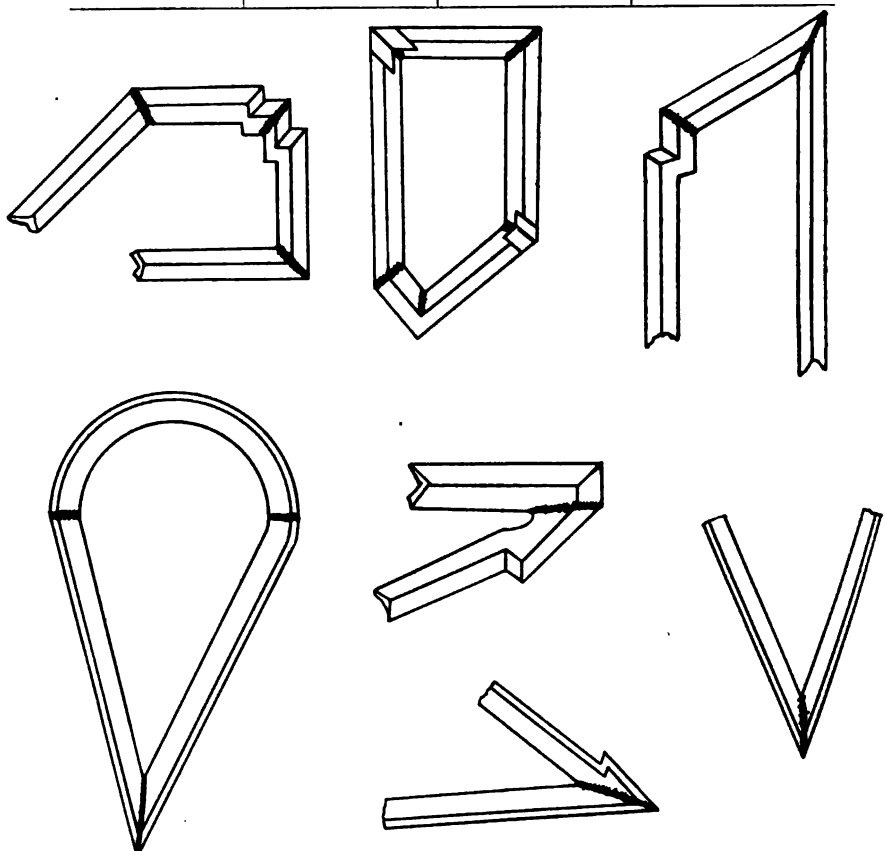
Fig. 7.

SECTION E

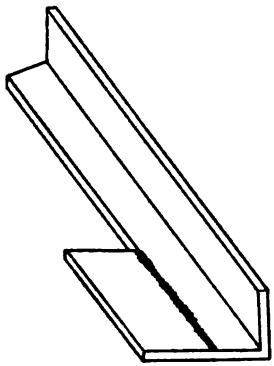
SUNDRY APPLICATIONS OF ELECTRIC WELDING SUPPLIED BY MR. E. J. RIGBY

Approximate Comparative Cost of Welding Angle Iron
Cost of Labor in Cents per Foot

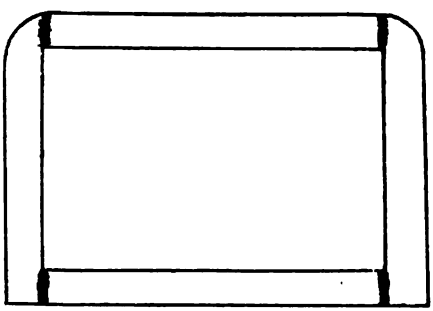
Size	Blacksmith Weld		Electric Weld Square or Beveled
	Square	Beveled	
2 x2	.12	.17	.06
2½x2½	.17	.20	.08
3 x3	.23	.25	.10
3 x3½	.25	.30	.12
3½x3½	.30	.35	.14
4 x3½	.35	.40	.16
4 x4	.40	.45	.18
5 x4	.45	.55	.20
6 x4	.65	.75	.22



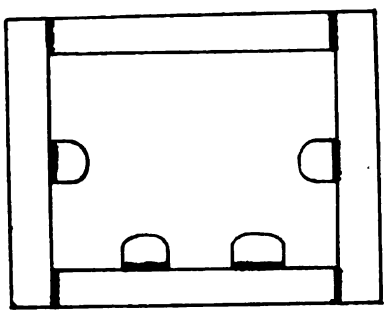
Sketches showing types of angle iron staples Welded by Electric Arc, cut by cold saw to required size and angle. In one Shipyard where twenty-two (22) fires had previously been used in an angle smithshop, it was found that by using an Electric Arc Welding Machine, two (⅔) of the fires could be dispensed with.



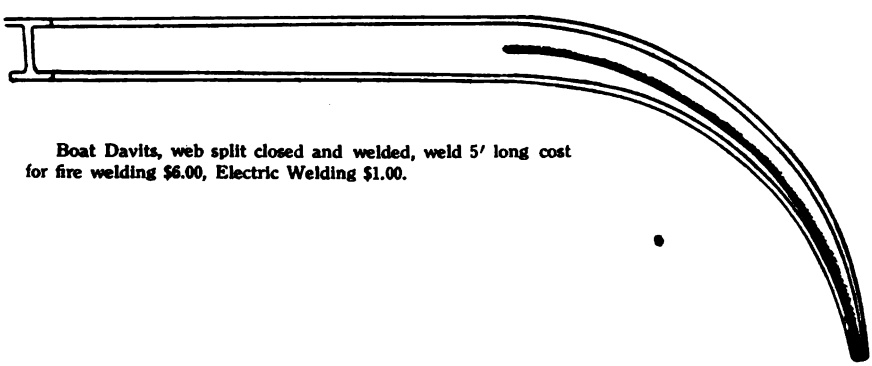
Angles can be welded out to any size required with Electric Arc at cost of .01 to .03 per inch, against anglesmith's fire welding .10 per inch.



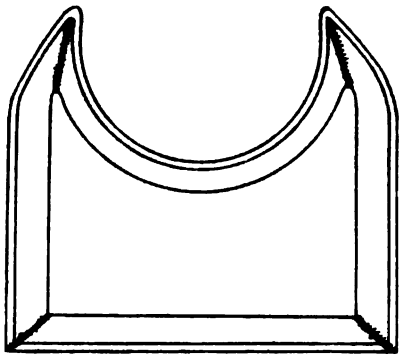
Door Frame made from flat bars of any size and Electric Arc welded with a saving of 75% compared with fire welding.



Watertight Doors 3″ X ¾″ flat bars.



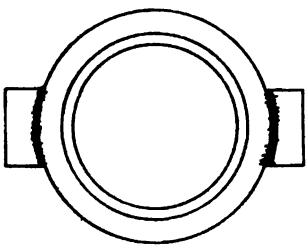
Boat Davits, web split closed and welded, weld 5′ long cost for fire welding $6.00, Electric Welding $1.00.



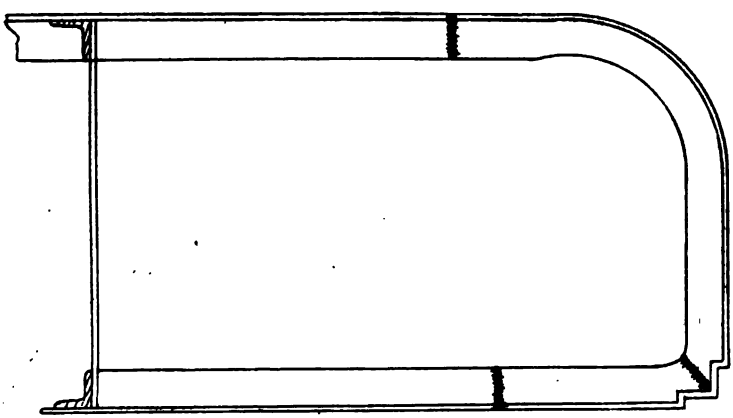
Cost for fire welding with solid points $7.75.

Saving by Electric Arc Welding $2.60.

Mast Platforms



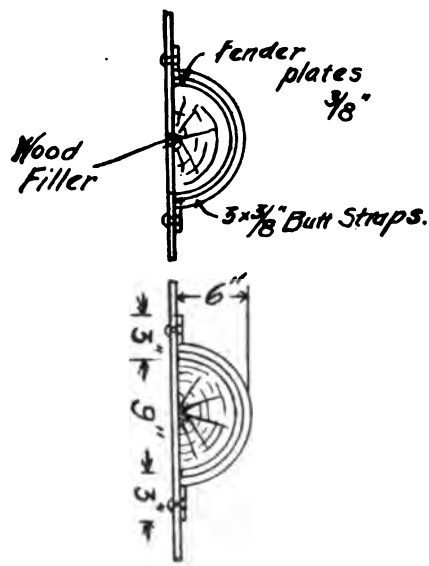
Angle Rings, with or without projections formed by anglesmiths and welded by Electric Arc at a Saving of 25 % at least.



Watertight Bulkheads 4" x 4 " Angles.
Federal Shipbuilding Company,
Newark, N. J.

Angles on keel plates and partitions are also welded at the butts.

Fenders on Mine Sweepers all round, Welded at Butts of plates after being riveted in position, by the Todd Shipyard Corporation at Tebo Yacht Basin, Brooklyn.



Approximate Comparative Cost of Welding Flat Bars, cost of labor in cents per foot.

SIZE	BLACKSMITH	ELECTRIC ARC	SAVING
2 x 3-16	.25	.05	.20
2 x 3-8	.28	.06	.22
2 x 1-2	.30	.07	.23
2 1-2 x 5-8	.35	.10	.25
2 1-2 x 3-4	.40	.12	.28
3 x 1-2	.50	.10	.40
3 x 3-4	.70	.20	.50

Report No. 14

MR. E. J. RIGBY'S DESCRIPTION OF ELECTRIC WELDING WITH FLUX-COVERED ELECTRODES.

I have received the following description of the Quasi Arc System of Electric Welding from Mr. E. J. Rigby, Consulting Engineer, who has had very considerable experience with this system in Australia, England and America.

SUMMARY OF CONTENTS.

INTRODUCTION.

NECESSITY FOR TRAINING OPERATORS FOR SHIPYARDS.

ADVANTAGES OF THE FLUX-COVERED METAL ARC PROCESS OF ELECTRIC WELDING.

ADVANTAGES OF ELECTRIC WELDING OVER GAS AND FIRE WELDING.

DEFECTS OF FORMER ELECTRICAL METHOD.

THE FLUX-COVERED METAL ARC ELECTRODES.

EQUIPMENT FOR FLUX-COVERED METAL ARC WELDING.

THE FLUX-COVERED METAL ARC PROCESS.

CUTTING BY THE FLUX-COVERED METAL ARC.

THE FLUX-COVERED METAL ARC PROCESS OF ELECTRIC WELDING.

Introduction

The flux-covered metal arc process of electric welding is in use in all the naval dockyards of Great Britain as well as in those of all the leading shipbuilders and manufacturing engineers, and is in use both for repair and new construction work.

So far as the process has been applied to the uniting of the entire hull plating it is at present confined to the building of a cross channel barge of 125-foot length, besides the auxiliary hull plating of battleships and cruisers.

From the experience and confidence gained in this way, designs have been prepared for more important ship structures. It is confidently expected by prominent naval architects that the cost of material and labor in building a ship will be considerably reduced, and the dead weight lightened by use of this process of welding.

In the shipyards welding is being adopted in conjunction with the usual methods of riveting and smithing, and for repairs, welding seams for water tightness in place of caulking, for oil and water tanks, bulkheads, making holes in armor plating, and welding in studs for attaching bilges, etc.

All the large engineering and steel plants also use the carbon and metal arc for repairing, and the making good of defective and fractured castings; for welding the seams of buoys, submarine mines, aerial torpedoes, bombs, etc.

Elaborate tests and experiments with a view to determining its further application to the welded construction of ships, boilers, etc., have already been carried out by the British Admiralty, and Lloyd's Registry have recently organized a series of severe vibratory tests which are now being made.

The wider adoption of electric welding in shipbuilding is a matter of supreme importance at the present time when the demand for tonnage is so great and urgent. It is realized that the reduction in the weight of material for a given strength will be effective, due to dispensing with the angle frame attachments, laps, rivets, etc., and the use of lighter weight of plating, due to the superior strength of the welded over the riveted joint. It should also bring in its train a reduction of the necessary man power connected with the skilled trades of punching, reaming, riveting, caulking, and smithing, as well as

a corresponding saving in time, plant and overhead charges over the present methods employed.

Necessity for Training Operators.

The rapid and wide adoption of the process in England and France, brought about by the necessities of the war situation has led to a great demand for operators, and the irregular quality of the work produced as the result of the scarcity of thoroughly trained workmen, directs attention to the reason why electric welding has been so long in taking the prominent place in construction work which its merits deserve.

In the past too much emphasis has been laid upon the fact that a green man could quickly learn how to operate electric welding equipment because of its simplicity, while little or no attention was given to training operators who would study the work and become skilled workmen capable of enlarging the scope of their trade and the quality of the work they produced.

While simple welding can be done with a fair degree of success by semi-skilled workmen such work as that found in shipyards and engineering repair shops needs more skilled mechanics. Electric welding has advanced to such a degree of success that it must now be recognized as a trade demanding the attention of thoroughly trained operators.

Welding with the electric arc is a trade of some skill and requires both practice to acquire the manual dexterity to manipulate it properly and instruction in the proper use of the apparatus employed, also the control and regulation of the current-supply necessary to perform any given piece of work.

Both the size of the electrodes used and the mass of the material to be welded will vary in different jobs requiring specified current at the correct pressure to give the amounts of heat necessary. It may, therefore, be stated that electric welding is a trade, requiring considerable skill, although the degree of proficiency is easily attained for the execution of repetition work. To assist in the supply of electric welding operators, the executive which controls the allocation of oxygen and acetylene in Britain have a staff of demonstrators who are available to train local labor in the application of such welding systems as are employed to greatly hasten the output of munitions including ship and aircraft construction. It was found that such initial instruction was most necessary to give a proper understanding of the uses of electric welding and the methods of applying the process to the class of work at the several factories.

Welding by means of the electric arc will supersede many of the riveting operations of today, and designers of ships and construction work will undoubtedly arrange their details to suit it, as soon as they have confidence that they can get operators able to make consistently good welded work.

Advantages of the Flux-Covered Arc Process of Electric Welding.

The efficiency of a welded joint must be determined not only by its tensile strength, but also by a consideration of the nature of the changes introduced by welding, in the structure of the metal of the work and this fact must be borne in mind when designing parts to be welded.

The essential characteristics of a satisfactory fusion weld are—

Firstly—That the metal in the welded joint shall be pure, and free from all traces of iron oxide; and

Secondly—that the thermal disturbance to the structure of the surrounding metals by the welding process shall be reduced to a minimum.

Advantages of Electric Welding Over Gas and Fire Welds.

The superiority of electric welding over gas and fire welding is consequent on the extremely localized character of the heat generated by the electric arc, thereby resulting in a smaller area of disturbance and also in the elimination of the necessity for any pre-heating of the work. The difficulty of localizing the heat in gas welding is liable to lead to imperfect welding at certain places of junction, owing to such places not having been brought to a welding temperature and has the further disadvantage, owing to the wide area over which the heat is diffused, that the welds are left in a condition of greater stress due to the contraction of the cooling metal.

Defects of Former Electrical Methods

Fusion welding has hitherto been effected by means of the carbon arc or by using iron rods as electrodes, which have not been satisfactory in work required to withstand pressure, and in the welding of alloyed or high carbon steels, excepting when special skill was employed in the operation. Such welds are frequently deteriorated by pitting, due to the particles of the slag, formed in the fusion, adhering to the surface, and oxidation of the fused metal exposed to the atmosphere absorbing oxygen which reacts and combines with the carbon in the steel to form gas, and with the iron to form oxide, resulting in porosity and breaking up of the structure of the metal.

The importance of forming a joint which contains no trace of oxide is so great as to deserve particular emphasis. Not only does the presence of oxide greatly reduce the strength of the weld, but it renders the joint peculiarly liable to corrosion.

In view of the importance which the subject of corrosion bears to that of welding especially in shipbuilding, or when joints are exposed, the following notes are of interest:

Fundamentally, corrosion is electrolytic in character and depends on the difference in potential of contiguous areas. Commercial iron and steel contain areas which in the presence of an electrolyte (which may be merely atmospheric moisture) are capable of forming voltaic circuits, the necessary conditions being afforded by the presence of small particles of impurities or by local conditions of strain in the metal itself.

These impurities or strains give rise to areas of higher electrolytic potential, and form the electro-positive points which are first attacked by the corroding agents. Thus in a caulked joint corrosion will commence at the caulking, and similarly a riveted joint will be attacked round the rivet heads, owing to the local strain in the metal at these points.

In a welded joint, if the metal at the weld be less pure than the surrounding metal, the weld will be first attacked. Similarly, if the added metal be not homogeneous, local difference of potential in the weld itself will cause corrosion at the weld.

A microscopic examination of the metal deposited by an electrode with flux of proper constituents shows it to be of extraordinary purity, and it will be found by the usual laboratory tests to be always electro-negative to the surrounding metal.

Hence it follows, that such a weld will have an exceptionally high factor of resistance to corrosive influence.

Flux-Covered Metal Arc Electrodes.

(As Manufactured by the Quasi Arc Weldtrode Co.)

The quasi arc electrodes are composed of a metallic core, with a covering of blue asbestos yarn or other coating which is a ferrous silicate and in fusing acts as a reducing agent, and so effectually prevents oxidation of the deposited metal. The yarn is coated with sodium silicate, aluminum silicate, or the like, to vary the fusing temperature of the asbestos yarn.

This covering forms a fusible insulating casing around the metal core of such thickness that the metal core is supported by it when in contact with the work, at the proper distance and to a large extent eliminates the factor of manual dexterity in maintaining an arc of the proper length while the electrode is fusing. In addition to the fusible insulating covering, the electrode has combined with it a small quantity of a different metal capable of exerting a strong reducing action, that is, a metal such as aluminum, having a strong affinity for oxygen at the temperature at which the welding takes the place.

Aluminum is admirable for the purpose and is applied in the form of a fine wire wrapped in the blue asbestos covering in the proportion to the iron of about 0.2%. Nickel deposited

on the rods also serves the same purpose.

The aluminum as it fuses with the metallic core of the electrode, oxidizes and so prevents oxidation of the fusing metal. The alumina formed readily combines with and passes away with the slag, and so produces a homogeneous deposit in the weld.

Owing also to its reducing action, it also preserves to a considerable extent the original carbon of the steel from the oxidation which always occurs in fusion.

The Electrodes are supplied ready for use in standard lengths of 18 inches, and of various diameters, according to the size and nature of the work for which they are required. Electrodes of various types are supplied composing the following characteristics.

Mild Steel Electrodes of .1 carbon content suitable for general welding of mild steel or iron shipbuilding, constructional work, welding fish plates to tramway rails, tanks, wheel tires, filling steel castings, etc.

Carbon Steel Electrodes of .5 carbon content suitable for reinforcing worn parts of machinery, building up teeth of steel gear wheels, reinforcing tramway rail treads, etc.

Manganese Electrodes, of 14% manganese suitable for reinforcing or building up manganese crusher jaws, dredge bucket lips, tramway points and crossings, etc.

Special Electrodes, of mild steel in which the slag coating is made more viscous by addition of lime, suitable for boiler plate reinforcement and any overhead or vertical welding.

Equipment for Flux-Covered Metal Arc Welding.

The equipment required is simple and relatively inexpensive. Any source of current supply either A. C. or D. C. at a pressure of 100-110 volts may be utilized, and the maximum amount of current used by any one operator will not exceed 250 amperes for the heaviest welding operations. When several men are employed welding in a shipyard or works, the load is estimated to average 60 amperes at 100 volts or approximately 6 kilowatts per operator.

Each operator is provided with a BALANCING RESISTANCE and with a meter and switch for adjusting the current to suit the size of work and electrode he is using. The resistance is portable, weighing only about 150 pounds, and may be easily carried to any position where work is required to be done. The personal equipment of the operator consists of an ELECTRODE HOLDER, with length of flexible cable attached, and a WELDING SCREEN with correctly colored glasses to protect his eyes and enable him to observe the operation; he will also require a CHIPPING HAMMER and WIRE BRUSH for removing the slag.

The Flux-Covered Metal Arc Process.

The methods of use and the results obtained differ from the bare metallic and carbon arc fusion systems. It is rapid and perfect owing to the fact that the heat introduced into the weld is automatically governed by the nature of the special electrodes, the covering of which in the solid state is a non-conductor, and in its igneous state a good conductor of electric current, and as a secondary conductor it maintains electrical connections between the work and the metallic arc of the electrode, serving to confine and maintain the direction and length of the arc.

The electrode holder is connected up with the positive connection on the resistance by means of a flexible cable of suitable length, while the negative pole of the current-supply is attached to the work or metal bench on which the work to be welded rests, thus reversing the usual practice in metallic arc welding.

In operation, electrical contact is made by touching the work with the end of the electrode held vertically, thus allowing current to pass and an arc to form. The electrode still kept in contact with the work is then dropped to an angle, when the arc is partially destroyed owing to the special covering passing into the igneous state and acting as a secondary conductor. The action once started, the electrode melts at a uniform rate so long as it remains in contact, and leaves a seam of metal perfectly diffused into the work, the covering material acting as a slag floats, and spreads over the surface of the weld as it is formed.

The fused metal being entirely covered by the slag is thereby completely protected from all risk of oxidation. The slag covering is readily chipped or brushed off when the weld cools, leaving a bright, clean metallic surface.

Uniformly good and reliable results are obtained and no appreciable thermal disturbance is caused to the structure of the surrounding metal.

Cutting by the Flux-Covered Arc.

Steel plates or castings can be readily cut by the electrodes, and this feature is exceedingly useful when the oxygen blowpipe is not available. The method of procedure is to take a mild steel electrode of No. 8 gauge, dip it in water and with a current of about 200 amperes apply the point of the electrode to the plate or piece to be cut. The point of the electrode must be moved quickly up and down through the thickness of the plate, and the molten metal allowed to drop.

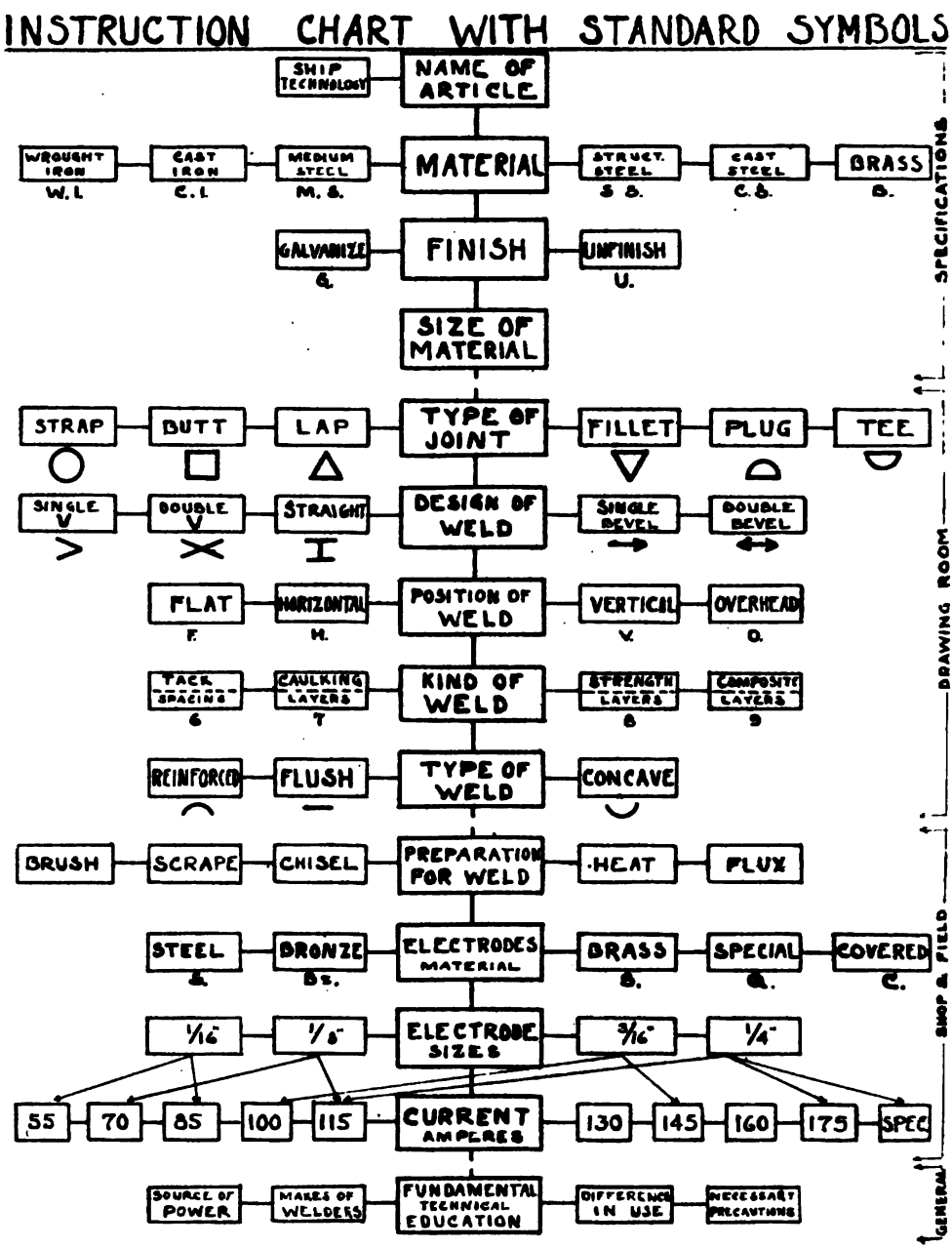
Report No. 15

NAVAL CONSTRUCTOR H. G. KNOX'S PLAN FOR NOMENCLATURE OF VARIOUS KINDS OF WELDS

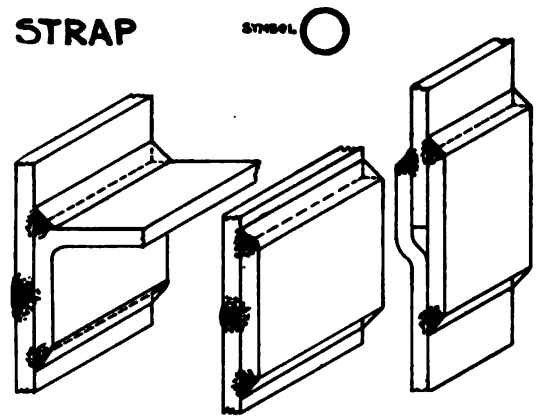
Naval Constructor Knox, of the United States Navy Yard, Norfolk, Va., brought forward the necessity for standardization of symbols, and the nomenclature of welds. His work was of an able pioneer nature. He transmitted the data which he had gathered to the Training Committee of the Electric Welding Committee, who, in conjunction with the Design Committee and the Research Committee, have developed from Naval Constructor Knox's early work a complete system of nomenclature and symbols, which are not only applicable to the general uses of the industry, but are also made convenient for the ship designer and draftsman.

This information follows herewith and will be added to from time to time by the Education and Training Section of the Emergency Fleet Corporation, by whom such information will be made available to the shipbuilder.

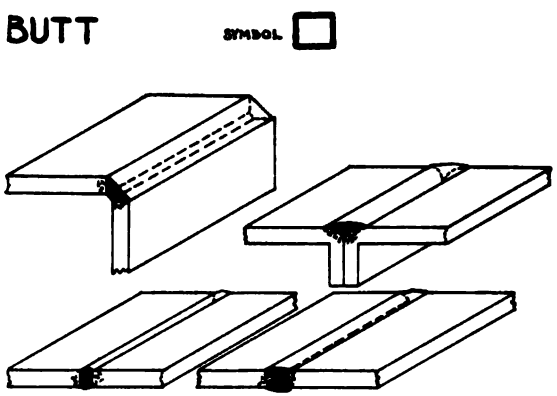
This plan has been developed by Mr. Hornor, of the Emergency Fleet Corporation (in collaboration with Mr. Knox), and the accompanying drawings and descriptions relate to a plan of nomenclature which should be considered as standard in America.


INSTRUCTION CHART WITH STANDARD SYMBOLS
SHIP TECHNOLOGY
NAME OF ARTICLE
WROUGHT IRON
W. I.
CAST IRON
C. I.
MEDIUM STEEL
M. S.
MATERIAL
STRUCT. STEEL
S. S.
CAST STEEL
C. S.
BRASS
B.
GALVANIZE
G.
FINISH
UNFINISH
U.
SIZE OF MATERIAL
STRAP
BUTT
LAP
TYPE OF JOINT
FILLET
PLUG
TEE
SINGLE V
DOUBLE V
STRAIGHT
DESIGN OF WELD
SINGLE BEVEL
DOUBLE BEVEL
FLAT
F.
HORIZONTAL
H.
POSITION OF WELD
VERTICAL
V.
OVERHEAD
O.
TACK SPACING
6
CAULKING LAYERS
7
KIND OF WELD
STRENGTH LAYERS
8
COMPOSITE LAYERS
9
REINFORCED
FLUSH
TYPE OF WELD
CONCAVE
BRUSH
SCRAPE
CHISEL
PREPARATION FOR WELD
HEAT
FLUX
STEEL
S.
BRONZE
Bz.
ELECTRODES MATERIAL
BRASS
B.
SPECIAL
Sp.
COVERED
C.
1/16"
1/8"
ELECTRODE SIZES
3/16"
1/4"
55
70
85
100
115
CURRENT AMPERES
130
145
160
175
SPEC
SOURCE OF POWER
MAKES OF WELDERS
FUNDAMENTAL TECHNICAL EDUCATION
DIFFERENCE IN USE
NECESSARY PRECAUTIONS
SPECIFICATIONS
DRAWING ROOM
SHOP & FIELD
GENERAL

TYPE OF JOINT

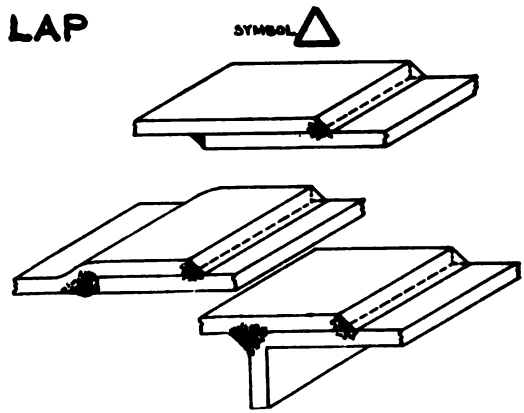


STRAP weld is one in which the seam of two adjoining plates or surfaces is reinforced by any form or shape to add strength and stability to the joint or plate. In this form of weld the seam can only be welded from the side of the work opposite the reinforcement, and the reinforcement of whatever shape must be welded from the side of the work to which the reinforcement is applied.

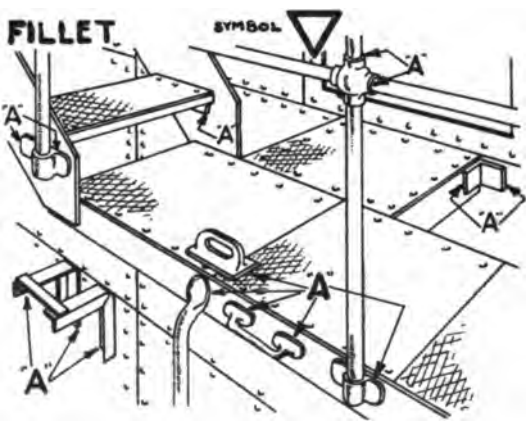


BUTT weld is one in which two plates or surfaces are brought together edge to edge and welded along the seam thus formed. The two plates when so welded, form a perfectly flat plane in themselves excluding the possible projective caused by other individual objects as frames, straps, stiffeners, etc., or the building up of the weld proper.

TYPE OF JOINT—Continued

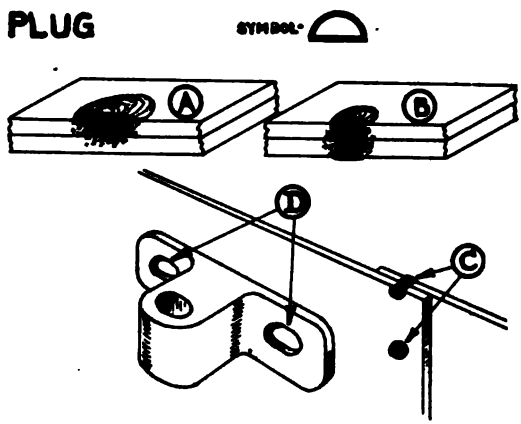


LAP weld is one in which the edges of two plates are set one above the other and the welding material so applied as to bind the edge of one plate to the face of the other plate. In this form of weld the seam or lap forms a raised surface along its entire extent.

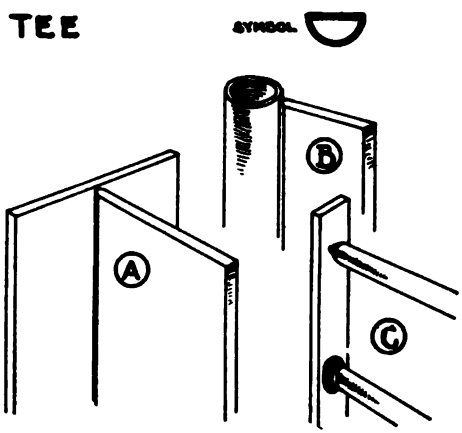


FILLET weld is one in which some fixture or member is welded to the face of a plate, by welding along the vertical edge of the fixture or member (see "welds" shown and marked "A" on illustration at left). The welding material is applied in the corner thus formed and finished at an angle of forty-five degrees to the plate.

TYPE OF JOINT—Continued

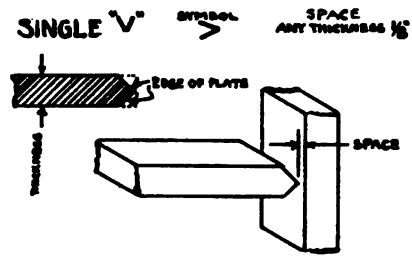


PLUG weld is one used to connect the metals by welding through a hole in either one plate (Fig. "A" or both plates (Fig. "B"). Also used for filling through a bolt hole as at (Fig. "C"), or for added strength when fastening fixtures to the face of a plate by drilling a countersunk hole through the fixture (Fig. "D") and applying the welding material through this hole, as at (Fig. "D"), thereby fastening the fixture to the plate at this point.

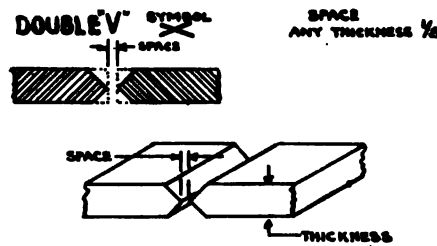


TEE weld is one where one plate is welded vertically to another as in the case of the edge of a transverse bulkhead (Fig. "A") being welded against the shell-plating or deck. This is a weld which in all cases requires EXCEPTIONAL care and can only be used where it is possible to work from both sides of the vertical plate. Also used for welding a rod in a vertical position to a flat surface, as the rung of a ladder (Fig. "C"), or a plate welded vertically to a pipe stanchion (Fig. "B"), as in the case of water closet stalls.

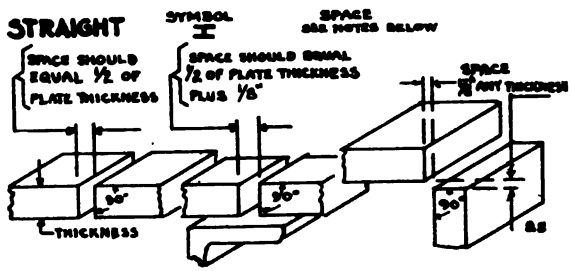
DESIGN OF WELD



SINGLE "V" is a term applied to the "edge finish" of a plate when this edge is beveled from BOTH sides to an angle, the degrees of which are left to the designer. To be used when the "V" side of the plate is to be a maximum "strength" weld, with the plate setting vertically to the face of an adjoining member, and only when the electrode can be applied from both sides of the work.

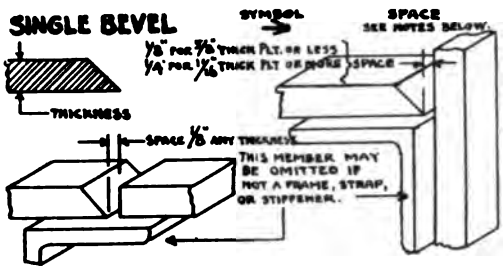


DOUBLE "V" is a term applied to the "edge finish" of two adjoining plates when the adjoining edges of both plates are beveled from BOTH sides to an angle, the degrees of which are left to the designer. To be used when the two plates are to be "butted" together along these two sides for a maximum "strength" weld. Only to be used when welding can be performed from both sides of the plate.

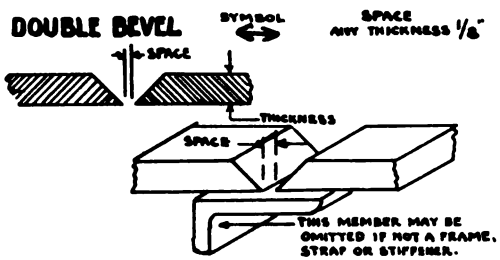


STRAIGHT is a term applied to the "edge finish" of a plate, when this edge is left in its crude or sheared state. To be used only where maximum strength is NOT essential, or unless used in connection with strap, stiffener or frame, or where it is impossible to otherwise finish the edge. Also to be used for a "strength" weld, when edges of two plates set vertically to each other, as the edge of a box.

DESIGN OF WELD—Continued

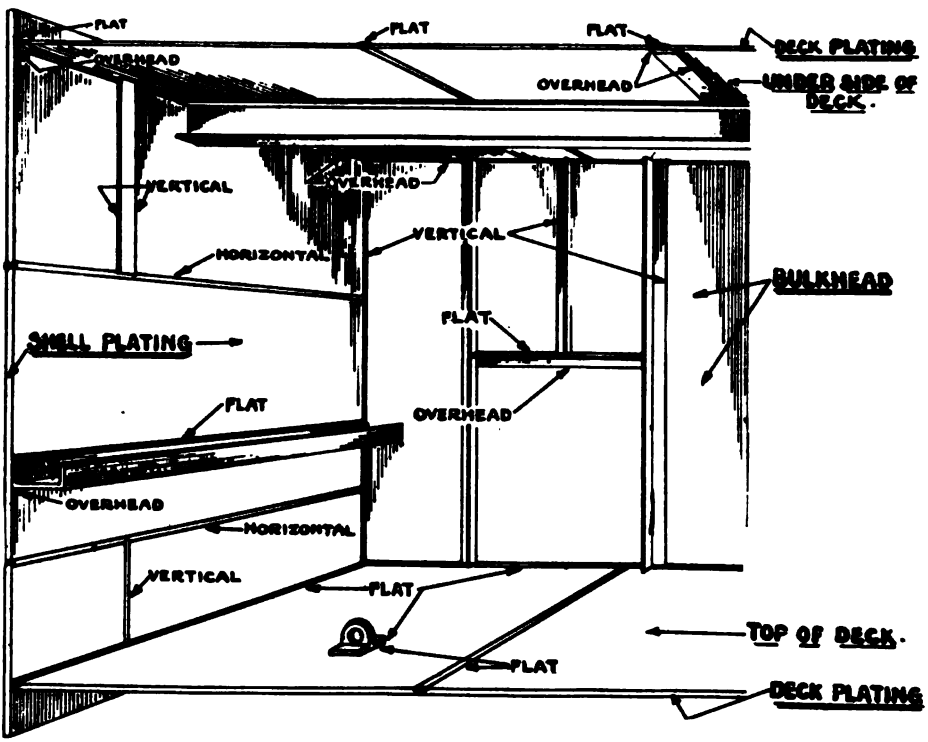


SINGLE BEVEL is a term applied to the edge finish of a plate, when this edge is beveled from ONE side only to an angle, the degrees of which are left to the designer. To be used for "strength" welding, when the electrode can be applied from ONE side of the plate only, or where it is impossible to finish the adjoining welding surface.



DOUBLE BEVEL is a term applied to the edge finish of two adjoining plates, when the adjoining edges of both plates are beveled from ONE side only to an angle, the degrees of which are left to the designer. To be used where maximum strength is required, and where electrode can be applied from ONE side of the work only.

POSITION OF WELD



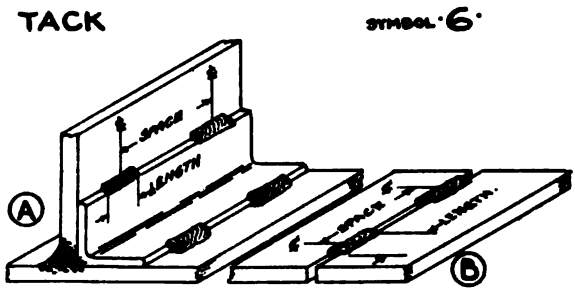
FLAT position is determined when the welding material is applied to a surface on the same plane as the deck, allowing the electrode to be held in an upright or vertical position. The welding surface may be entirely on a plane with the deck, or one side may be vertical to the deck and welded to an adjoining member that is on a plane with the deck.

HORIZONTAL position is determined when the welding material is applied to a seam or opening, the plane of which is vertical to the deck and the line of weld is parallel with the deck, allowing the electrode to be held in an inboard or outboard position.

VERTICAL position is determined when the welding material is applied to a surface or seam, whose line extends in a direction from one deck to the deck above, regardless of whether the adjoining members are on a single plane or at an angle to each other. In this position of weld, the electrode would also be held in a partially horizontal position to the work.

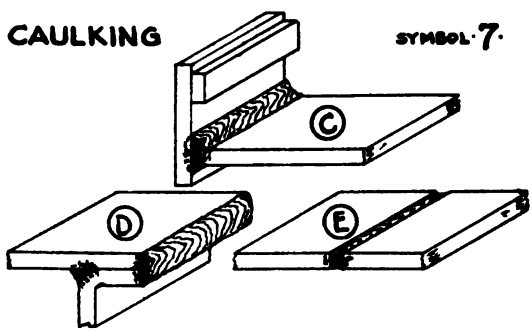
OVERHEAD position is determined when the welding material is applied from the under side of any member whose plane is parallel to the deck and necessitates the electrode being held in a downright or inverted position.

KIND OF WELD



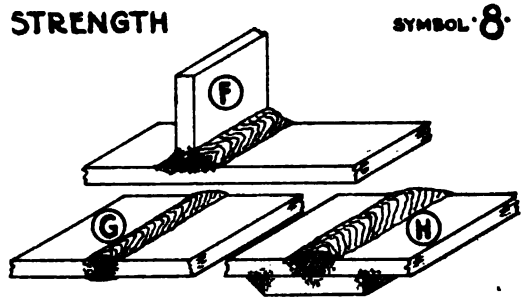
A TACK weld is applying the welding material in small sections to hold two edges together, and should always be specified by giving the SPACE from center to center of weld and the LENGTH of the weld itself. No particular "Design of weld" is necessary of consideration.

A TACK is also used for temporarily holding material in place that is to be solidly welded, until the proper alignment and position is obtained, and in this case, neither the LENGTH, SPACE or DESIGN OF WELD are to be specified.



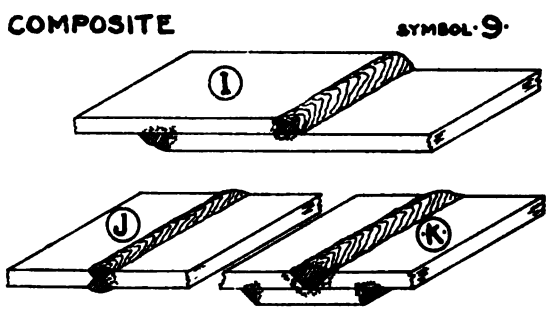
A CAULKING weld is one in which the density of the crystalline metal, used to close up the seam or opening, is such, that no possible leakage is visable under a water, oil or air pressure of 25 lbs. per square inch. The ultimate strength of a caulking weld is not of material importance, neither is the "Design of weld" of this kind necessary of consideration. The operator must be the judge in the number of layers needed for a tight weld, although the designer should specify a minimum amount of layers.

KIND OF WELD—Continued



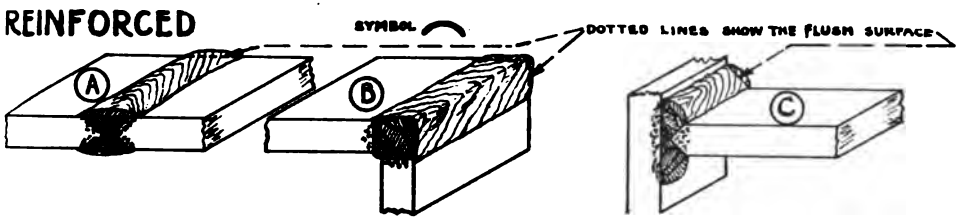
A STRENGTH weld is one in which the sectional area of the welding material must be so considered that its tensile strength and elongation per square inch must be equal to at least 80 per cent. of the ultimate strength per square inch of the surrounding material. (To be determined and specified by the designer). The welding material can be applied in any number of layers beyond a minimum specified by the designer.

The density of the crystalline metals is NOT of vital importance. In this form of weld, the "Design of weld" must be specified by the designer and followed by the operator.

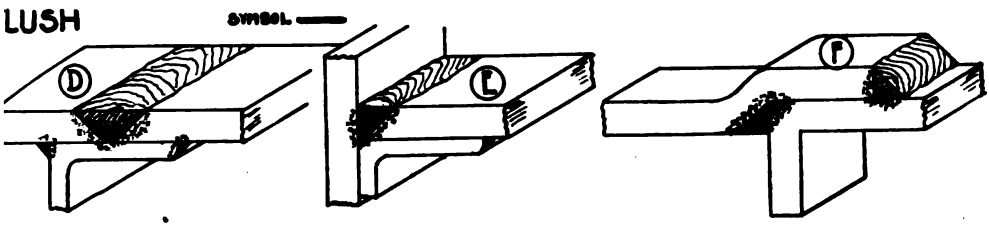


A COMPOSITE weld is one in which both the strength and density are of the most vital importance. The STRENGTH must be at least as specified for a "strength weld," and the density must meet the requirements of a "Caulking weld" both as above defined. The minimum number of layers of welding material must always be specified by the designer, but the welder must be in a position to know if this number must be increased according to the welder's working condition.

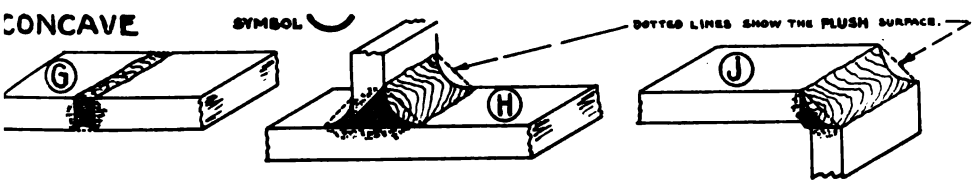
TYPE OF WELD



REINFORCED is a term applied to a weld when the top layer of the welding material is built up above the plane of the surrounding material as at Fig. "A" or Fig. "B" above, or when used for a corner as in Fig. "C." The top of the final layer should project above a plane of 45 degrees to the adjoining material. This 45 degrees line is shown "dotted" in Fig. "C" above. This type is chiefly used in a "Strength" or "Composite" kind of weld for the purpose of obtaining the maximum strength efficiency, and should be specified by the designer, together with a minimum number of layers of welding material.



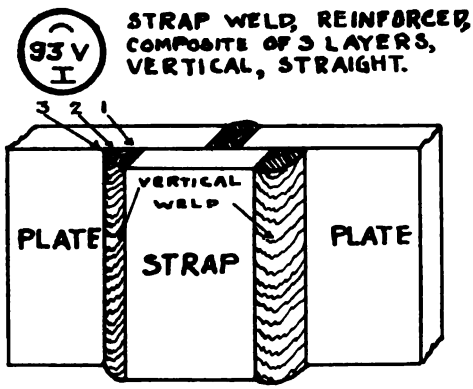
FLUSH is a term applied to a weld when the top layer is finished perfectly flat or on the same plane as on the adjoining material as shown at Figs. "D" and "E" above or at any angle of 45 degrees when used to connect two surfaces at an angle to each other as at Fig. "F" above. This type of weld is to be used where a maximum tensile strength is not all important and must be specified by the designer, together with a minimum number of layers of welding material.



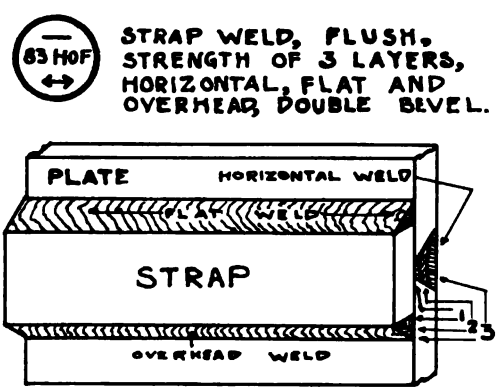
CONCAVE is a term applied to a weld when the top layer finishes below the plane of the surrounding material as at Fig. "G" above, or beneath a plane of 45 degrees at an angular connection as at Figs. "H" and "J" above.

To be used as a weld of no further importance than filling in a seam or opening, or for strictly caulking purposes, when it is found that a minimum amount of welding material will suffice to sustain a specified pound square inch pressure without leakage. In this "Type of weld" it will not be necessary for the designer ordinarily to specify the number of layers of material owing to the lack of structural importance.

COMBINATION OF SYMBOLS

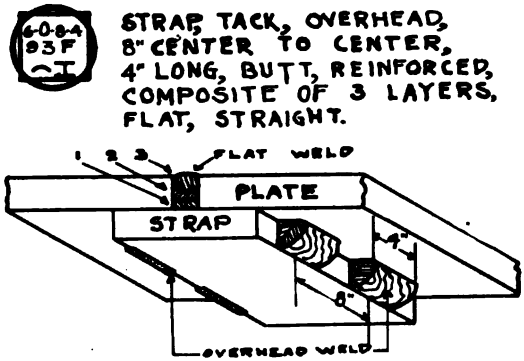


This sketch and symbol shows a strap holding two plates together, setting vertically, with the welding material applied in not less than three layers at each edge of the strap, as well as between the plates with a reinforced composite finish, so as to make the welded seams absolutely water, air or oiltight, and to attain the maximum tensile strength. The edges of the strap and the plates are left in a natural or sheared finish. This type of welding is used for most particular kind of work where maximum strains are to be sustained.

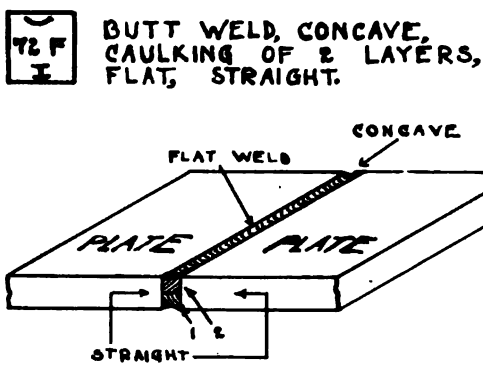


This illustration shows a strap holding two plates together horizontally, welded as a strength member with a minimum of three layers and a flush finish. Inasmuch as the strap necessitates welding of the plates from one side only, both edges of the plates are beveled to an angle, the degrees of which are left to the discretion of the designer. The edges of the strap are left in a natural or sheared state, and the maximum strength is attained by the mode of applying the welding material, and through the sectional area per square inch exceeding the sectional area of the surrounding material.

COMBINATION OF SYMBOLS (Continued)



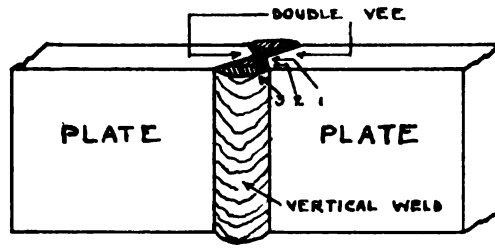
This symbol represents two plates butted together and welded flat, with a composite weld of not less than three layers, and a reinforced finish. A strap is attached by means of overhead tacking, the tacks being four inches long and spaced eight inches from center to center. In this case, the welding of the plates is of maximum strength and water, air or oiltight, but the tacking is either for the purpose of holding the strap in place until it may be continuously welded, or because strength is not essential. All the edges are left in their natural or sheared state.



The symbol shown represents a Butt Weld between two plates with the welding material finished concaved and applied in a minimum of two layers to take the place of caulking. The edges of the plates are left in a natural shear cut finish. This symbol will be quite frequently used for deck plating or any other place where strength is not essential, but where the material must be water, air or oiltight.

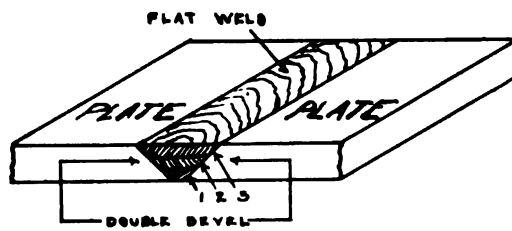
COMBINATION OF SYMBOLS (Continued)

BUTT WELD, REINFORCED, STRENGTH OF 3 LAYERS, VERTICAL, DOUBLE VEE.



This symbol is used where the edges of two plates are vertically butted together and welded as a strength member. The edges of the adjoining plates are finished with a "Double Vee" and the minimum of three layers of welding material applied from each side, finished with a convex surface, thereby making the sectional area per square inch of the weld, greater than that of the plates. This will be a conventional symbol for shell plating or any other members requiring a maximum tensile strength, where the welding can be done from both sides of the work.

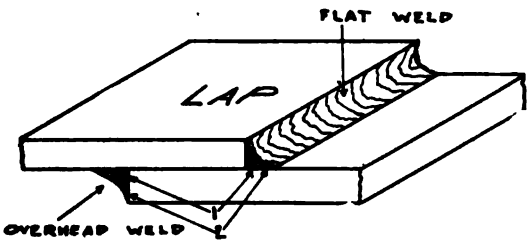
BUTT WELD, FLUSH, COMPOSITE OF 3 LAYERS, FLAT, DOUBLE BEVEL.



This symbol shows two plates butted together in a flat position where the welding can only be applied from the top surface. It shows a weld required for plating where both strength and water-tightness are to be considered. The welding material is applied in a minimum of three layers and finished flush with the level of the plates. Both edges of the adjoining plates are beveled to an angle, the degrees of which are left to the discretion and judgment of the designer, and should only be used when it is impossible to weld from both sides of the work.

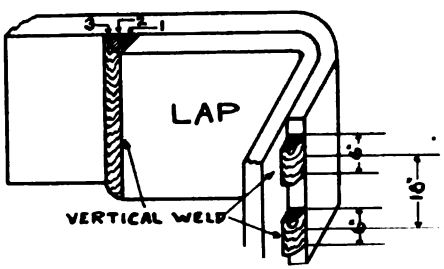
COMBINATION OF SYMBOLS (Continued)

LAP WELD, CONCAVE, CAULKING OF 2 LAYERS, OVERHEAD AND FLAT, STRAIGHT.



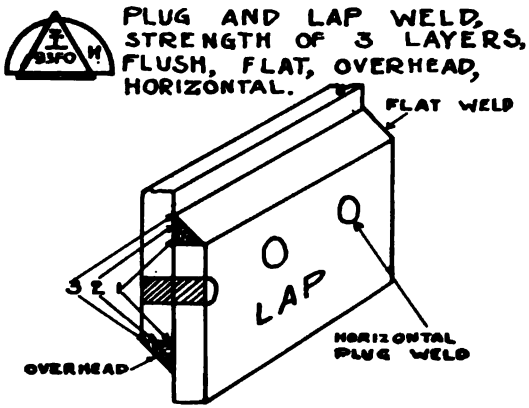
The sketch shows the edges of two plates lapping each other with the welding material applied in not less than two layers at each edge, with a concaved caulking finish, so applied as to make the welded seams absolutely water, air or oiltight. The edges of the plates themselves are left in a natural or sheared finish. Conditions of this kind will often occur around bulkhead door frames where maximum strength is not absolutely essential.

LAP WELD, REINFORCED, STRENGTH OF 3 LAYERS AND TACKING, 18" CENTER TO CENTER, 6" LONG, VERTICAL, STRAIGHT.

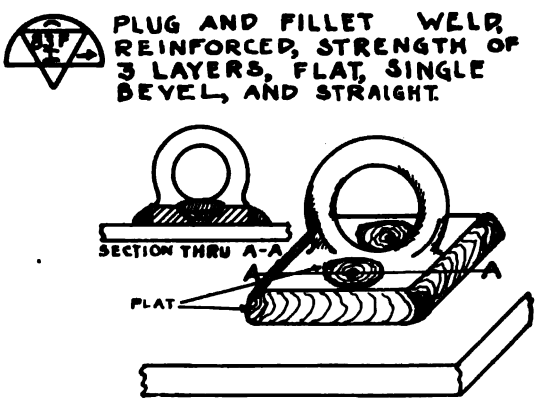


The illustration herein shown is somewhat exaggerated as regards the bending of the plates, but it is only shown this way to fully illustrate the tack and continuous weld. It shows the edges of the plates lapped with one edge welded with a continuous weld of a minimum of three layers with a reinforced finish, thereby giving a maximum tensile strength to the weld, and the other edge of the plate, tack welded. The tacks are six inches long with a space of twelve inches between the welds or eighteen inches from center to center of welds. In both cases, the edges of plates are left in a natural or sheared state.

COMBINATION OF SYMBOLS (Continued)

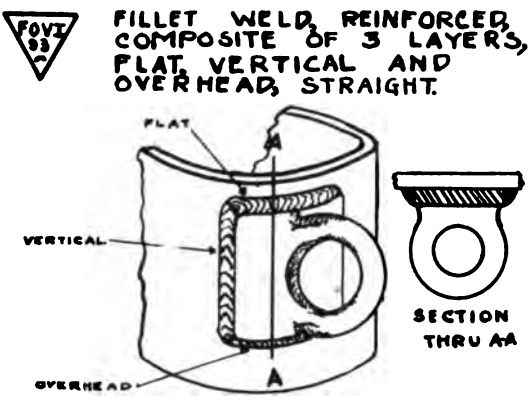


The sketch shows a condition exaggerated, which is apt to occur in side plating where the plates were held in position with bolts for the purpose of alignment before being welded. The edges are to be welded with a minimum of three layers of welding material for a strength weld and finished flush, and after the bolts are removed, the holes thus left are to be filled in with welding material in a manner prescribed for strength welding. The edges of the plates are to be left in a natural or sheared state, which is customary in most cases of lapped welding.

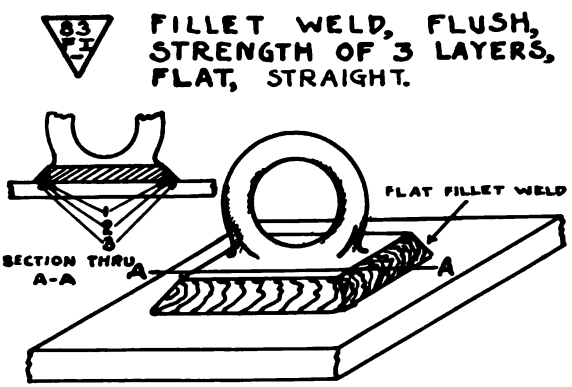


The adjoining sketch shows a pad eye attached to a plate by means of a fillet weld along the edge of the fixture, and further strengthened by plug welds in two countersunk holes drilled in the fixture. The welding material is applied in a flat position for a strength weld with a minimum of three layers and a reinforced finish. The edges of the holes are beveled to an angle, which is left to the judgment of the designer, but the edges of the fixture are left in their natural state. This method is used in fastening fixtures, clips or accessories that would be subjected to an excessive strain or vibration.

COMBINATION OF SYMBOLS (Continued)



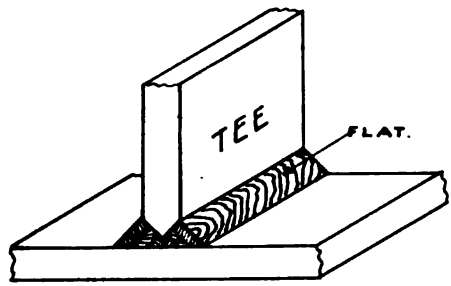
This illustration shows a fixture attached to a plate by means of a composite weld of not less than three layers with a reinforced finish. The fixture being placed vertically, necessitates a combination of flat, vertical and overhead welding in the course of its erection. Although a fixture of this kind would never be required to be watertight, the composite symbol is simply as a possibility of a combination.



This symbol represents a fixture attached to a plate by a strength fillet weld of not less than three layers, finished flush. The edges of the fixture are left in their natural state, and the welding material applied in the corner formed by the vertical edge of the fixture in contact with the face of the plate.

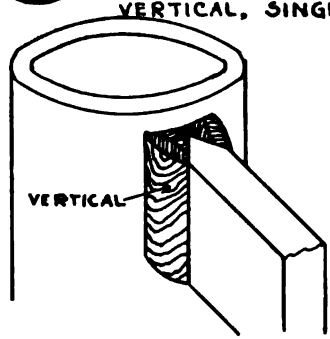
COMBINATION OF SYMBOLS (Continued)

TEE WELD, FLUSH, STRENGTH OF 3 LAYERS, FLAT, SINGLE VEE.



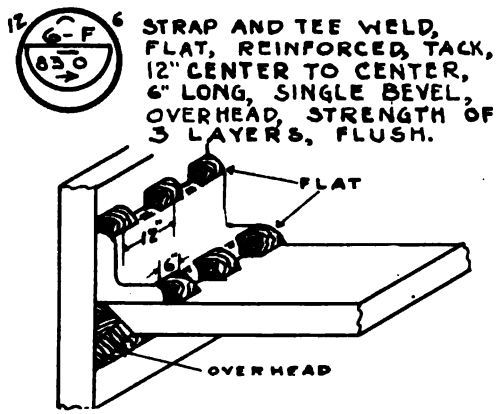
The adjoining sketch illustrates the edge of a plate welded to the face of another plate, as in the case of the bottom of a transverse bulkhead being welded against the deck plating. To obtain a maximum tensile strength at the joint, the edge of the plate is cut to a "Single Vee" and welded on both sides with a strength weld of not less than three layers, and finished flush. This would be a convenient way of fastening the intercostals to the keelsons. In this particular case, the welding is done in a flat position.

TEE WELD, REINFORCED, STRENGTH OF 3 LAYERS, VERTICAL, SINGLE VEE.

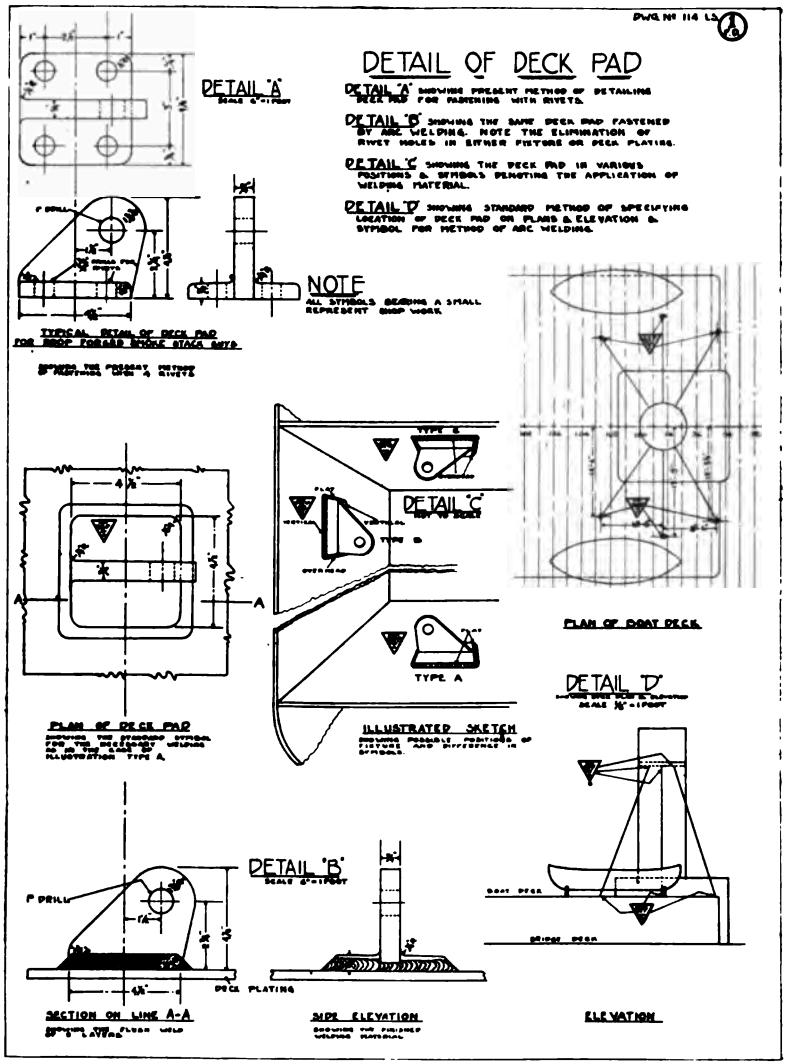


This symbol shows another case of Tee Weld with the seam setting in a vertical position, and the welding material applied from both sides of the work. The edge of the plate is finished with a "Single Vee" and a minimum of three layers of welding material is applied from each side, finished with a convex surface, thereby making the sectional area, per square inch of the weld, greater than that of the plate allowing for a maximum tensile strength in the weld.

COMBINATION OF SYMBOLS (Continued)



The illustration herein shown represents an example of the possible combination of symbols. An angle iron is tack welded to the plate in the form of a strap or stiffener, though in actual practice, this might never occur. The tacks are spaced twelve inches from center to center, and are six inches long, and applied in a flat position, with a reinforced finish. As the strap prevents welding the plate from both sides, the edge of the plate is beveled, and the welding material applied for strength in not less than three layers in an overhead position and finished flush. Note that in specifying tack welds, it is essential to give the space from center to center of weld, and length of weld by use of figures representing inches placed either side of the circumscribing symbol of the combination.


DWG No 114 L3
DETAIL OF DECK PAD
DETAIL 'A' SHOWING PRESENT METHOD OF DETAILING DECK PAD FOR FASTENING WITH RIVETS.
DETAIL 'B' SHOWING THE SAME DECK PAD FASTENED BY ARC WELDING. NOTE THE ELIMINATION OF RIVET HOLES IN EITHER FIXTURE OR DECK PLATING.
DETAIL 'C' SHOWING THE DECK PAD IN VARIOUS POSITIONS & SYMBOLS DENOTING THE APPLICATION OF WELDING MATERIAL.
DETAIL 'D' SHOWING STANDARD METHOD OF SPECIFYING LOCATION OF DECK PAD ON PLANS & ELEVATION & SYMBOL FOR METHOD OF ARC WELDING.
DETAIL 'A'
NOTE
ALL SYMBOLS BEARING A SMALL REPRESENT SHOP WORK
TYPICAL DETAIL OF DECK PAD FOR SHOP FORGED BRONZE STACK BASE
SHOWING THE PREFERRED METHOD OF WELDING DECK & RIVETS
PLAN OF DECK PAD
SHOWING THE STANDARD SYMBOL FOR THE NECESSARY WELDING AS PER THE CASE OF ILLUSTRATION TYPE A.
TYPE C
DETAIL 'C'
TYPE B
TYPE A
ILLUSTRATED SKETCH
SHOWING POSSIBLE POSITIONS OF FIXTURE AND DIFFERENCE IN SYMBOLS.
PLAN OF BOAT DECK
DETAIL 'D'
P DRILL
DECK PLATING
SECTION ON LINE A-A
DETAIL 'B'
SIDE ELEVATION
ELEVATION

Report No. 16

SECTION A

INVESTIGATION OF ELECTRIC WELDING METHODS AND CONTROL.

THE WESTINGHOUSE COMPANY'S ACTIVITIES IN ELECTRIC WELDING.

Mr. C. E. Skinner, of the Westinghouse Electric and Manufacturing Company, Pittsburgh, has kindly submitted a discussion prepared by Mr. O. H. Eschholz, on some phases of electric welding, including:

(A) Investigation of electric welding methods and control.
(B) Electric welding equipment.
(C) (1) Preparation of work for welding.
(2) Arc and electrode data.
(3) Added metal necessary.
(D) Strength and structure of electric arc welds.
(E) (1) Micro photographs of welds.
(2) Sundry tables and charts.

REPORT ON ARC WELDING EXP. ORDER 6-5509.

SUMMARY.

Object

Briefly, the purpose of the investigation was to obtain a better knowledge of the factors which determine the production of good welds and to accumulate data which would assist in the wider application of welding.

Procedure.

Observations of equipment, performance and welding operation were made at the works. Tests were run on the 150 ampere, experimental constant current generator and a 500 ampere, 75 volt, constant potential generator installed in Research Test No. 1. Test welds were made by experienced shop operators, the type of weld representing commercial welding conditions. No tests were made on competitive apparatus.

RESULTS AND CONCLUSIONS.

Welding Equipment.

(1) The importance of the generator and circuit design in the production of a good weld has been overstated in welding literature.

(2) In general, an expert operator can obtain practically as good results with an indifferent equipment as with one embodying every refinement.

(3) It is possible by comparatively simple modifications to greatly reduce the degree of skill required for proper electrode manipulation and thereby greatly extend the field of arc welding.

(4) It is our conclusion that an equipment having a low generator and arc voltage, a constant arc current characteristic and series reactance will facilitate the production of good welds to the extent that further improvement in welding will be dominated by type of electrode used and operator equation.

(5) One or more of the following types of equipment may prove desirable for varying application.

(A) Constant current generator, 150 to 200 amperes capacity, having characteristics suited to arc welding for a single operator.

(B) Constant potential generator, 45 volts, for multiple operators utilizing series reactance and resistance in each circuit.

(C) Constant potential generator for miscellaneous use for permitting a voltage variation from 45 to 75, enabling the operator to draw a long arc with pencil or carbon electrode, as occasion demands.

Electrode Holders.

(6) Overheating of pencil or carbon holder grips greatly increases the time for welding and the skill required to maintain a constant short arc length.

(7) The following modifications are suggested:

(A) Shunt electrode cable around grip and thoroughly heat-insulate grip from electrode and cable contact.

(B) Modify pencil contact so operator can release or admit pencil without changing grip and touching hot section of holder.

(C) Heat-insulate electrode contact spring.

(D) If the demand for heavy cutting justifies the development expense, it would be desirable to further modify the carbon holder to prevent excessive generation of heat at electrode contacts and electrode proper and to provide the end of holder with insulating buffers to eliminate short circuiting arc on marking deep cuts.

Welding Glasses.

(8) The Corning Glass Co. has developed a number of glasses of varying density and selective absorption for arc welding. Grades No. 6, No. 8 and No. 12 of Noviweld have been found to greatly reduce eye strain.

Automatic Control.

(9) It is the consensus of opinion that any automatic equipment requiring the use of switches and movable parts undesirably complicates the welding system.

Welding.

(1) The strength of a steel weld is affected by a number of variables which are all under the operator's control. In general it may be stated that welds made by an average operator with suitable electrodes will have an ultimate tensile strength of 25,000 to 35,000 lbs. per square inch, an elongation of 3 to 5% and reduction of area of 7 to 11%.

Under favorable conditions of small weld, skilled operator and proper electrode, a tensile strength as high as 50,000 pounds per square inch, an elongation of 11% and reduction of area of 15% may be secured.

(2) To obtain a strong weld, good fusion and low slag content are of prime importance, thermal disturbance of adjacent metal and shrinkage strains are of less importance, excepting when welding cast iron.

(3) The use of a short arc during welding greatly improves fusion, reduces slag formation and time and energy for making weld.

(4) Porosity is caused by excessive oxidation of molten deposit as well as by gas occlusion. The use of a short arc reduces porosity by enveloping the incandescent deposit with an inert oxide flame, which prevents access of oxygen.

The porosity produced on breaking arc at electrode is due to exposing the crater deposit to rapid oxidation when the arc is lengthened. The degree of porosity is determined by speed of breaking arc, arc length (dependent on circuit characteristics), arc current and electrode.

(5) The electrode used determines to a large extent the stability of arc current, fusion, amount of slag, and weld porosity.

(6) In passing from the bare metal pencil to the weld the electrode material is refined, the alloying constituents becoming oxidized and condensing as slag; the filler metal thus approximates the chemical composition of commercially pure iron.

(7) Roebling wire gave the best results for general use of the electrodes tested.

(8) When a non-porous single deposit is required, the Quasi Weldtrode gives best results and Roebling better than Norway.

(9) The superior performance of Roebling is attributed to the use of manganese and the comparative purity of the metal. A large percentage of manganese results in excessive slag. It is doubtful whether Roebling has the most advantageous manganese content.

(10) The ideal electrode should enclose the vapor stream and molten deposit with a permanent, inert gas. It should feed quietly, without the sputtering and globule formation characteristic of most electrodes. Its melting point should be the same as that of the metal welded and the molten metal should solidify quickly and not flow over unfused portions of weld.

An electrode having such characteristics would greatly reduce the skill required in the production of a good weld and would assure the transference to the weld of suitable alloying constituents.

The Quasi Weldtrode and Carbonized Electrode are approximations to this ideal.

(11) Data on weld strength, electrode diameter and current, cutting rate for C. I. and exhibits of various types of welds and deposits are contained in body of report.

Detailed discussion is appended on:

(1) Welding Equipment.
(2) Welding.
(3) Strength and Structure of Steel Welds.
(4) Cast Iron Welding.

SECTION B

ELECTRIC WELDING EQUIPMENT.

Welding Equipment.

The function of a special welding equipment is to simplify the production of reliable welds. This necessarily involves that the degree of skill required and the opportunities for producing inconsistent results be reduced to a minimum. Furthermore, that welding accessories, such as electrode holders, masks, glasses and clothing should be selected which offer the maximum of comfort and ease in the manipulation of the arc.

Constant Current vs. Constant Potential.

The terms used in designating welding equipments have unfortunately led to considerable confusion. The heat developed in the arc and at electrode terminals is essentially a function of the current flowing. Since a uniform welding temperature is desired throughout the welding operation and as the difficulty of manipulating electrode increases with current fluctuations, it is obvious that a practically constant arc current must be maintained, if reliable welds are to be secured. This has been recognized by constant potential equipment manufacturers in the insertion of a series resistance in the arc circuit. It is evident, regardless of the type of generator used, that the purpose of every welding equipment is to maintain a constant arc current and, therefore, such equipments are essentially constant current systems.

Whether a constant current system having a constant current generator is preferable to one using a constant potential generator is dependent on the constancy of current required, complexity, flexibility and cost of the system. It appears to have been overlooked that a constant current machine does not necessarily maintain a constant arc current, in fact the attached oscillograms clearly show large instantaneous variations exceeding those obtained when using a constant potential generator with series resistance.

The relative ease with which good work can be produced depends upon the design of the equipment. It is well known that less skill is required to maintain an arc supplied from a 125-volt source than from a 35-volt source, due to greater

constancy of current with larger permissible variation in arc length at the higher voltage. However, it is also generally conceded that a short arc length must be maintained to prevent excessive porosity, slag formation and to secure good fusion. A high voltage supply requires less skill for the maintenance of the continuity of the arc, however, by permitting considerable fluctuation in arc length, inferior welds may readily be produced.

Generator and Circuits.

The simplest form of welding unit for a single operator is the constant current generator with series reactance; for multiple operators, a constant potential generator having a flat voltage characteristic and series reactance and resistance for each operator. Automatic control, involving switching devices, complicates the system, increases liability of shutdowns, first cost, maintenance and grade of operator.

Arc Characteristics.

Oscillograms A, B, C, D, E, F, G show the arc current and voltage characteristics under greatly varying conditions.

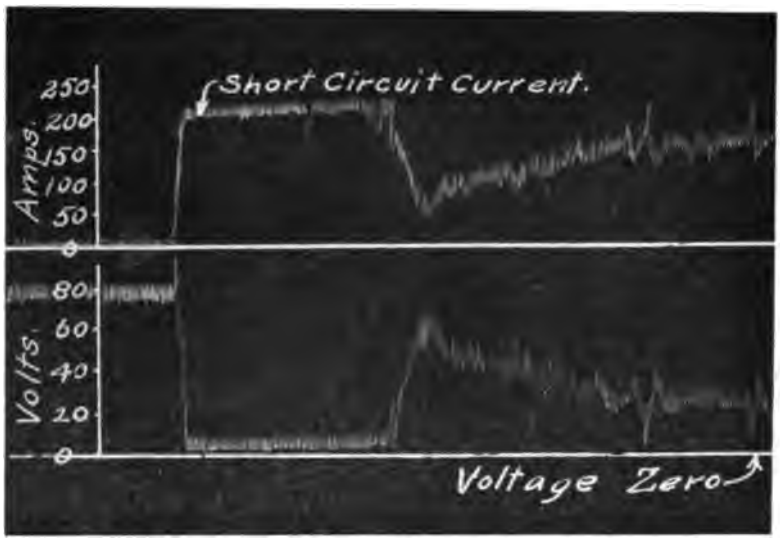
No Series Reactance.

Oscillograms A and C show the normal performance of constant potential and constant current generators. It will be noted that a more constant current is obtained from the 75-volt, C. P. generator than from the experimental 150-ampere, C. C. machine. An inspection shows the frequency with which electrodes stick to weld and the difficulty encountered in preventing breaking of arc on separating electrode. It should be noted that for the same average current load the instantaneous current at start, which facilitates "freezing," is much higher with this particular C. C. than with the C. P. generator.

Series Reactance.

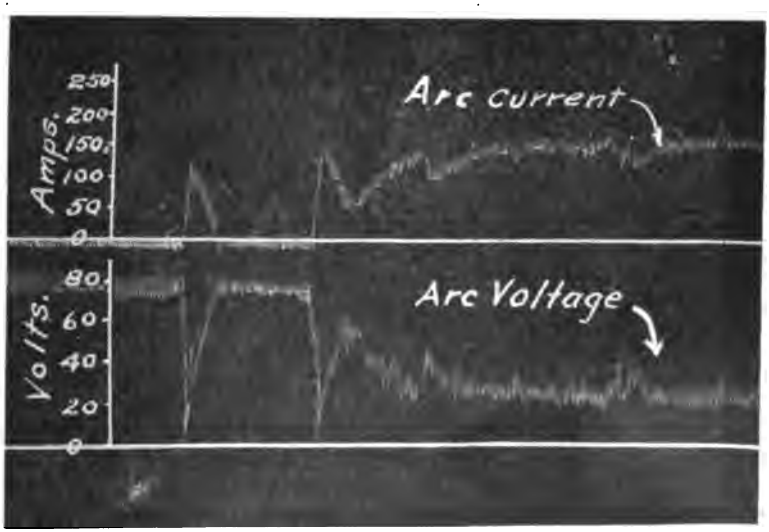
Oscillograms B and D show the improvement in constancy of current obtained by the use of a series reactance of .0035 henries. The initial current rush in A is 220 amperes, on drawing the arc the current decreases to 40 amperes or less, but when using reactance as shown in B the instantaneous current is but 150 amperes, which then drops to 65 amperes. Oscillogram C shows a starting current of 460 amperes and a reduction to 30 or less amperes on separating electrodes, while Oscillogram D shows respectively 340 and 160 amperes.

It is evident that by checking the rush of current at making contact and by sustaining it on drawing the arc, the reactance largely prevents fusion of electrode and breaking of arc, thus reducing the skill required in electrode manipulation.



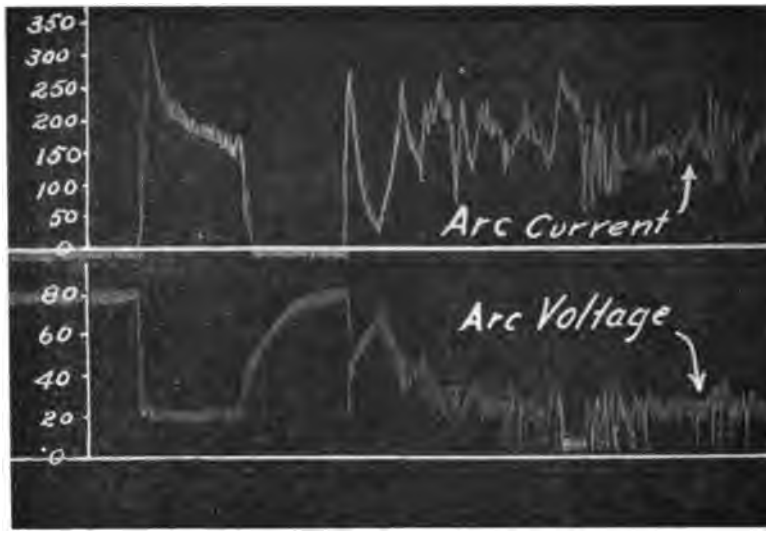
A

Arc Current and Arc Voltage starting and operating characteristics obtained when welding mild steel plates with Roebling electrode, energy supplied from constant potential generator. (Note "Freezing" at start).



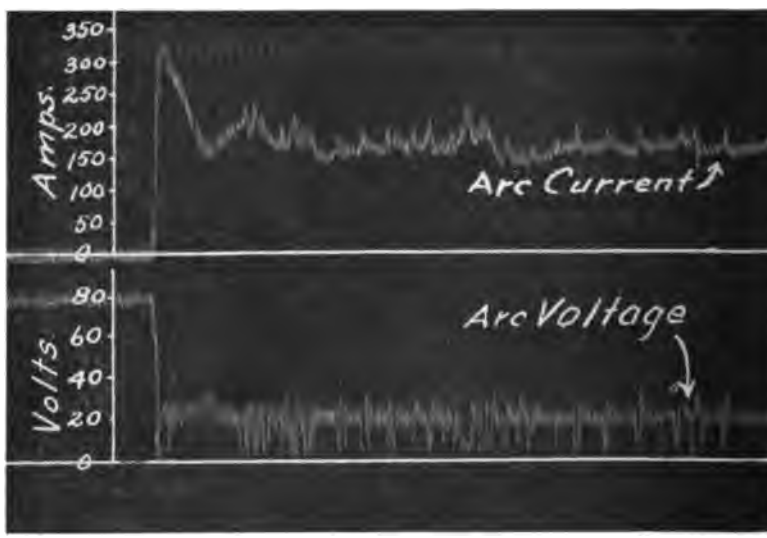
B

Same as A except reactance in series with arc. Note reduction in voltage and current fluctuations.



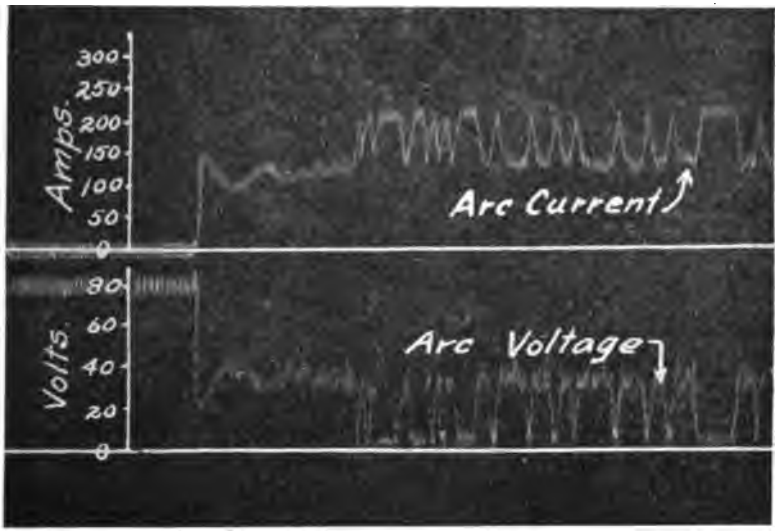
C

Same as A except energy supplied from "constant current" generator without series reactance.



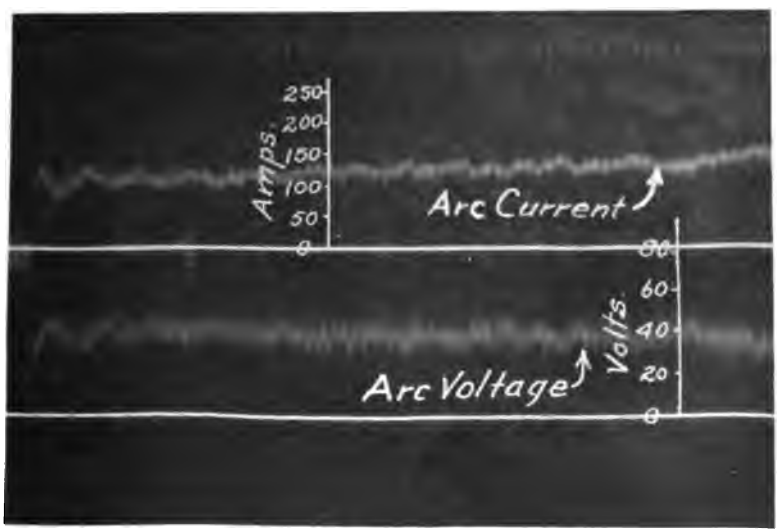
D

Same as C except with external series reactance.



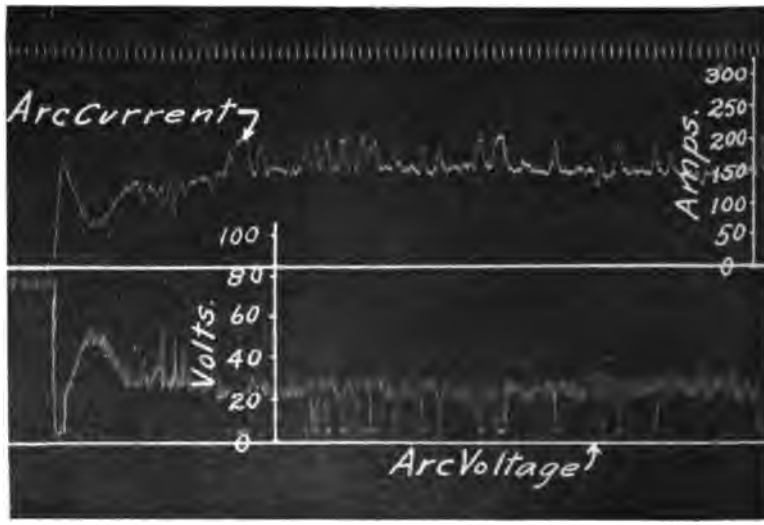
E

Same as B (energy supplied from constant potential generator with series reactance) except ¼" Hot Rolled Steel Electrode. Note electrode characteristics determine magnitude of fluctuations to a greater degree than circuit characteristics.



F

Same as E except ⅛ inch dia. covered electrode used.



G

Same as B except characteristics obtained on welding cast iron plate.

Other oscillograms have shown the current variation with C. P. generator operated at 65 volts. No change in current fluctuation was noticeable. A skillful operator can maintain an arc continuously at 35 volts with the use of a series reactance. It is believed that a welder accustomed to a 60-volt C. P. supply without series reactance would have no serious difficulty in utilizing a 45-volt supply with series reactance. It is obvious that the reactance serves only to check rapid current changes and, therefore, the current fluctuation would be greater for same arc length variation when using the low voltage unit.

It is conceivable that a **skilled operator** would use this characteristic to **vary the concentration of arc energy on the weld** and thus enable him to compensate for differences in temperatures between various zones of the welded joint.

Electrode.

The intermittent current peaks shown on these oscillograms are produced by changes in arc resistance caused by electrode characteristics. The following films clearly show the current variations obtained, due solely to type of electrode used:

B—Roebling electrode.

E—Hot rolled steel electrode.

F—Quasi Weltrode.

Variations produced by Norway, Toncan and cold rolled steel electrodes were similarly observed.

The Quasi, Norway and Roebling show an increase of less than 25% over normal current while the use of H. R. S. causes an increase of 70%. The large variation in current obtained by using Toncan, H. R. S. or C. R. S. increases the difficulty of manipulating the arc and, therefore, of making a satisfactory weld.

Polarity.

With the polarity reversed, current peaks are increased due probably to the tendency for a larger globule of metal to form with the electrode positive and short circuiting arc.

Arc Length.

For reasons already noted the use of a short arc is essential. Although most operators quickly learn to maintain the proper length, the use of a high voltage supply permits considerable variation. Automatic limitation of arc length may be secured by the use of arc limit switches or low voltage supply. The use of switching equipment definitely limits arc length to a predetermined value and compels the operator to maintain a short arc. However, the results obtained do not appear to warrant the complicated control. A low voltage

supply is a compromise which avoids the use of a complex equipment but does not permit as close an adjustment of arc length, particularly in systems which require series resistance and reactance.

ACCESSORIES.

Pencil Holder.

Continuous operation for half an hour on an arc current varying from 150 to 175 amperes caused the pencil holder to become uncomfortably hot, thereby greatly increasing the difficulty of maintaining a constant arc length.

The importance of heat insulation in carbon holder design is shown by the fact that the handle of a special holder, in which the grip was shunted by the cable, became excessively hot in 8½ minutes when cutting with 650 amperes, due largely to the heat conducted from the incandescent carbon.

Glasses.

Discomfort may be experienced with most glasses due to the transmission of a considerable quantity of radiations of the longer wave lengths. Most operators become accustomed to the resulting red blur. However, when eye strain develops the use of Noviweld glasses, No. 8 or No. 12, is advised (Corning Glass Co.).

The preference for a hood or mask depends upon the accessibility of the weld. For practically all, except possibly overhead welding, the hood is preferable, due to better ventilation and the fact that its weight is supported by the shoulders.

Clothing.

Direct as well as reflected arc light will produce severe burns. Loosely woven, light clothing does not protect operator from the ultra-violet radiation. It is desirable to provide welders with a heavy, closely woven fabric which will absorb and deflect both the objectionable radiations and sprays of molten metal.

SECTION C

(1) PREPARATION OF WORK FOR WELDING
(2) ARC AND ELECTRODE DATA.
(3) ADDED METAL NECESSARY

Welding

With an equipment available embodying the above features, the success of arc welding is dependent upon the knowledge, skill and judgment of operator. By the choice of weld scarf, electrode, arc current and by proper electrode manipulation, the operator largely determines degree of fusion, slag content and porosity of weld.

Fusion-Weld Scarf

Figs. 1, 2 and 3 show the degree of fusion obtained when welding 1″ thick steel plate and using (see Section E, Page 247.)

(1) A 60° scarf.
(2) A 60° scarf with section separated 1/8″.
(3) A 90° scarf with section separated 1/8″.

Better results were obtained in weld shown in Fig. 2, owing to the greater accessibility of the bottom of the V. Less skill is required to satisfactorily fuse a 90° scarf than a 60° scarf. In general it is advisable to use a 90° scarf with a separation of sections of 1/16″ to 1/8″. When heavy material is welded the angle of the upper part of scarf may be reduced to 60° to shorten time of filling weld. A good weld will always show a projection of filler material on reversed side, which is a rough check on the degree of fusion at the bottom of V.

Arc Length

Figs. 4 and 5 illustrate fusion obtained with respectively a short, 22 volts, and a long, 38 volts, arc when operating a Norway iron electrode on 125 amperes. The better fusion, greater concentration of deposited material and smaller zone of thermal disturbance is evident when using the short arc. Figs. 6 and 7 show respectively, the surface porosity obtained with short and long arcs. The short arc deposit is practically free from porosity due to the protection of molten metal from rapid oxidation by the enveloping flame of vapor oxides. When using a long arc, draft currents blow this oxide from

the weld surface, thereby exposing the deposited metal to oxidation. Since the use of a short arc concentrates both the electrode deposit and arc flame, rapid filling and good fusion are secured.

Arc Current and Electrode Diameter

Curve No. 1 and Table 1 give the desirable limiting values of arc current and electrode diameter which operator should observe. This information is based on the experience of a large number of shop welders. It will be noted that the $\frac{5}{32}$" electrode and 150 amperes arc current have the greatest range of usefulness.

Fig. 9 shows the poor fusion and porous structure obtained when using a current of approximately 115 amperes on 1" material, while Fig. 8 shows the improvement secured by increasing the current to approximately 160 amperes.

Curve No. 2 plotted from data obtained by Mr. Oetting, shows the variation of weld strength for different arc currents. It will be noted that at 100 amperes the strength of weld was not sufficient to permit machining, while at 175 amperes it approximated the strength of filler material.

Welded joints do not appear to be appreciably affected by small variations in electrode diameter. In general, too large an electrode diameter for a given current results in slow deposition of metal; increasing the arc current to obtain more rapid deposition will result in excessive heating of weld with the liability of melting through weld. An excessive current also produces deeper fusion, but not better fusion, and hence requires more filling material. Too small an electrode diameter for a given current will result in the dropping of large globules from electrode and hence imperfect fusion; reducing arc current, when mass of weld is large, will also reduce degree of fusion.

Electrode

The electrode used determines to a considerable extent current variations (see oscillograms), hence ease of arc manipulation, porosity and slag content.

Porosity

Figs. 10 and 11 show respectively, polished surface of Roebling and Quasi deposits. It appears impossible to prevent porosity altogether. However, the illustrations show a lesser degree of porosity for Quasi, due, doubtless, to the protecting slag coating. The use of Norway iron results in greater porosity. Blow holes are caused by the liberation of occluded gases, the reduction of oxides and consequent formation of CO, and the inclusion of vapors or permanent gases during the welding operation.

Slag

Slag consists largely of oxides of iron and alloying constituents. Its presence is controlled by choice of electrode and its manipulation. The illustrations of weld sections show the relative amount of slag and porosity in 5" wide, 1" thick welds obtained with different electrodes. The excess of slag present in a Quasi weld is due to the formation of large quantities of SiO_2, Al_2O_3 and MgO, from the vaporization of the asbestos wrapping. The large amount of slag in the Norway weld is caused by the heavy oxide coating on electrode as well as the large slag content characteristic of this iron. The improved appearance of the Roebling weld is due to the cleaner iron and the presence of an appreciable amount of carbon and manganese, which tend to prevent formation of iron oxide.

Electrode Manipulation.

The skill and knowledge required is dependent upon the nature of the welding operation. In some industries, notably railroad repair shops and our own works, the welder is confronted with widely divergent problems which demand considerable ingenuity, a broad mechanical knowledge and a thorough comprehension of the capabilities of arc welding, for satisfactory solution. However, there is a rapidly growing list of manufacturers who utilize arc welding as a process in the production of standard apparatus and, therefore, achieve good results with cheaper labor.

The welding apprentice should be cautioned against exposing any part of his body to either direct or reflected arc light, and be assured that the low voltage electric circuit is harmless.

The operator should always endeavor to maintain the shortest possible arc length. This is particularly difficult for a beginner, owing to frequent "freezing" of electrode due to irregular deposition, current fluctuation and incorrect rate of feeding electrode. It is generally admitted that the instinct to maintain a short arc length can be developed quicker by starting with a high generator voltage and, as the operator becomes more adept, decreasing the voltage.

Preparation.

The sections of the weld should first be properly scarfed either by cutting, chipping or melting excess material with carbon electrode, until the requisite angle of 90° is secured between scarfed faces. In practically every weld more than ½" thick it is advisable to separate sections approximately ⅛". The series resistance or the generator voltage should be adjusted to deliver the proper arc current. With a metal pencil

of suitable composition and diameter the operator is ready to begin welding. In general the welded piece should form the positive terminal and the pencil electrode the negative, excepting for sheet welding.

Welding.

The operator should fill the V section in layers beginning at the apex of the V. A short arc length should be maintained and electrode held so that the arc flame will envelop the newly deposited metal. Good fusion will be secured if the arc bites into the scarfed surface forming shallow pools of molten metal. Since the temperature of the weld increases with prolonged operation the filling process is slower at the start. Proper fusion and minimum slag content are of prime importance. To secure the desired fusion every part of the scarfed as well as deposited metal surfaces must become the crater of the arc. It should be noted that poor fusion is obtained when the molten metal overruns the adjacent surfaces unless the arc is brought in contact with the overrun area. A description of the color of the deposited material or slag is apt to lead to confusion owing to the different colors of protecting glasses in use. However, it is advisable as a rule to bring the filler metal and adjacent parts of the weld to a bright red heat, as viewed by the naked eye, in order to secure partial annealing. Some annealing may be secured by burying hot weld in a sand box.

Slag.

Slag usually floats on the molten metal as a dull colored scale, since it cools faster than the iron. As a considerable amount of slag may be suspended in the metal the deposited material should be maintained sufficiently long in the molten state to assure the flotation of all slag; this can be collected readily about a nucleus by a circular movement of the electrode and worked to the edge of the weld or chipped and brushed off.

Thermal Treatment.

Owing to the localization of intensive heat, considerable strains are produced in filler and weld body due to unequal contraction. By depositing the filler material in layers these strains are largely reduced because partial annealing is secured. As advised above, wherever practicable the whole weld should be completely annealed. On cooling the alignment of the weld shanks will be changed, unless they are rigidly held, which is undesirable, due to the internal strains produced, in most cases an experienced welder can allow for such distortion.

Inspection.

A weld may be readily inspected for fusion and slag content by observing the surfaces of sections parallel and at right angles to the weld after having been ground and etched with

dilute nitric acid. This examination is so simple that it should be utilized as a check by all employers and instructors. The slag content and blow holes can be readily detected. Proper fusion is obtained when the scarfed surface shows an irregular outline without slag intervening between it and the filler metal.

Whether or not the operator is maintaining a short arc length is indicated by the arc voltmeter. In general a voltage of 22 or less should be obtained. With certain electrodes such as the Quasi Weldtrode this may be exceeded.

Welding Time.

This depends on the amount of preparation required, the necessity for preheating or annealing, the arc current, electrode diameter, degree of care exercised to secure thorough fusion and minimum slag.

The time required for filling the 5" wide by 1" thick H. R. S. welds scarfed at 90° varied from 20 minutes to one hour. The shortest period was obtained when using a 24" long, ¼" diameter electrode, with but moderate care in removing slag, the longest period when using a 5/32" diameter 16" electrode and exercising every precaution to eliminate slag and internal stresses. A fair average time for this type of weld should be 35 minutes or approximately 10 cubic inches an hour.

Filling.

The volume of electrode material required depends also upon the above factors. In the test welds the volume of electrodes required varied from 1.4 to 2.3 times the volume of weld. It is believed that under average conditions an electrode volume of approximately 1.8 times that of weld volume would be required. This large excess clearly shows that with the present method large amounts of slag are produced.

Cutting.

In view of the data accumulated and published by Mr. Auel and the G. E. Review, no tests have been made on the rate of cutting steel plates.

It is generally known that cutting with the electric arc produces a wide gap leaving the metal with very irregular edges. In view of the applicability of the oxyacetylene and oxyhydrogen torches to this field it does not seem expedient to advise the adoption of arc cutting on a large scale, excepting for cast iron.

SECTION D

STRENGTH AND STRUCTURE OF ELECTRIC ARC WELDS.

Weld Strength.

The strength of welded sections of hot rolled steel, boiler plate, cold rolled steel, pure iron and cast steel is determined in practically every case by the degree of fusion and the strength of filler. No narrow limits can be set at the present time of the strength of such welds and it must be recognized that due to the type of electrode used, arc manipulation, size of weld and difficulty of depositing filler, large variations in weld strength will occur. With further study and development the degree of reliability and such characteristics as ductility and tensile strength will be improved.

Strength Data.

A competent operator using Roebling electrodes should consistently produce steel welds having a tensile strength greater than 25,000 pounds per square inch and averaging 40,000 pounds. Depending upon the care exercised and the size of welded section, the tensile strength may at times approximate 50,000 pounds per square inch. The ductility of the average weld is poor, due to rapid cooling and the presence of dissolved slag. However, a capable operator should produce welds having an elongation of more than 3% and a reduction of area exceeding 7%.

Table No. 2 shows the strength of various welds. All welds with the exception of No. 21 were made by welding 1″ thick by 5″ wide hot rolled steel plates scarfed to 90° and separated ⅛″. Weld No. 21 was made by joining 1″ square hot rolled steel bars scarfed 60° and spaced ⅛″.

It will be noted that:

(1) Roebling electrodes gave the best results.

(2) Considerable variation of strength occurs with same electrode.

(3) Considerable variation of strength for round and square section due to slag distribution.

(4) The use of borax weakened weld.
(5) The 1" square weld gave best results.
(6) Norway weld produced by melting Norway rod into weld with carbon electrode is stronger than that obtained by using a Norway electrode.
(7) Hot rolled steel electrodes produce very poor welds.
(8) Fair welds were obtained with all the electrodes tested excepting H. R. S.
(9) All welds failed either at line of fusion or in filler.

In addition, Curve No. 2 shows the variation in weld strength for different welding currents when using Norway iron electrodes. The strength data is somewhat unfavorable owing to the use of Norway electrodes, a 60° scarf and no separation of scarfed sections. The shape of the curve shows excellently, however, the rapid variation of weld strength over a comparatively small range in current.

Electrodes.

No definite conclusion has been reached as to the effect on weld strength of employing electrodes having a high content of carbon, tungsten, silicon, manganese, etc. The analyses made and discussed under "Composition" show very clearly the refining action occurring and the small per cent of alloying constituent, present in the electrode, transferred to the filler.

Unquestionably the physical characteristics of welds are improved by using electrodes of appreciable carbon, manganese, etc., content, owing to their tendency to oxidize more readily and thus prevent formation of iron oxide. It is anticipated that further development of electrodes will result in increasing the dependability of arc welded joints as well as their strength and ductility and in decreasing the skill required in electrode manipulation.

Composition.

In Table No. 3 the chemical composition of electrode material is shown before and after deposition as filler in the weld. The marked refining effect due to the oxidation of the vaporized metal is evident. The variation in the amount transmitted is due to slight changes in arc length, draft conditions and globule formation. H. R. S., which produces the weakest welds, deposits the metal in large globules and, therefore, a greater per cent of the alloying constituents is transferred.

Structure.

The process of welding is essentially that of continuously casting small amounts of refined electrode material. Rapid and irregular rates of cooling are, therefore, inherent characteristics of the operation. Examinations of welded sections always show a number of typical zones indicative of different rates of heat treatment.

Fig. 12 shows the sequence of structures present in a section through a deposit of Norway iron on mild steel magnified 10 times. Figs 12 A, B, C, D and E show zones 1, 2, 3, 4, 5 at 300 diameters.

Zone 1 shows the original structure of slowly cooled low carbon steel. The dark areas show the location of the carbon. Here the carbon occurs as iron carbide in the metallographic constituent known as pearlite.

Zone 2 shows the structure of zone 1 as modified by heating to a temperature of approximately 750° C and cooling to below 600°C. within roughly 5 minutes. The temperature has, therefore, been high enough to cause the carbon of the pearlite areas to diffuse into the surrounding metal to some extent and the rate of cooling was sufficiently great to prevent reformation of the well-defined pearlite areas. Physically, this zone may be somewhat harder and more ductile although the difference, if any, would be but slight.

In Zone 3 the temperature and time of heating have exceeded those producing the structure in Zone 2. Considerable diffusion of the carbon has occurred and the reformation of the definite pearlite areas has been incomplete. Compared to the original material this would have slightly higher tensile strength and a slightly lower ductility.

Zone 4 shows metal which has been heated to a temperature approximating 950°C. The diffusion of the pearlite areas has been complete and the rate of cooling so rapid that the pearlite areas formed are small and very uniformly distributed. In comparison with the original material this would have a higher tensile strength and nearly as good ductility.

Zone 5 shows the metal which has been fused by the action of the arc. Experience indicates that the ductility of metal melted under the highly oxidizing conditions of the welding process is greatly impaired. This is probably due to the presence of dissolved oxides, nitrides or even gases. The rate of cooling is so great that the deposited metal retains portions of the above compounds either mechanically or in solid solution. It is highly probable that the low ductility of the fused metal is due to these compounds. The location of the impurities is marked by the irregular discontinuous lines.

Strength of Altered Structure.

These illustrations show that the welding operation does not materially change the structure of the steel beyond the fused portion. To completely check this conclusion tests were made by striking an arc on standard ½" diameter test pieces. The results of the test are shown in Fig. 13.

Test pieces No. 7 and No. 6-1, which broke beyond the arc contact zone, show the strength of the mild steel tested. It is evident that these tests support the above conclusions. Since

the arc drawn from No. 5-1 and No. 5-2 was supplied from a constant current generator and that from 6-1, 6-2 from a constant potential generator, the further conclusion is reached that the starting arcing conditions, regardless of the type of system used, do not materially affect the strength of the metal. Although no appreciable difference in strength was secured, a magnification of the cross section through the point of arc contact shows the same sequence of structures to a depth of about $\frac{1}{16}$" discussed above.

Weld Structure.

Figs. 14 A, B, C and D show enlarged to 400 diameters the structure of Norway iron welds. Fig. 14 A illustrates the normal pearlitic structure of slowly cooled low carbon steel, similar to Fig. 12. Figs. 14 B and 14 C show respectively the appearance of good and bad junctions between original bar and deposited electrode material. Fig. 14 D shows a section of the filler metal parts of which are also shown in Figs. 14 B and 14 C. Fig. 14 D is of particular importance in that it clearly shows the occurrence of impurities and cementite in well defined planes or needles.

Figs. 3 and 15 show the fusion and structure obtained in a Roebling weld.

Fig. 16 shows a weld made using a Norway electrode and Fig. 17 a weld made by melting a Norway rod with carbon arc. It is evident that less slag is formed by the latter process due to the enveloping and protecting flame of CO_2.

Figs. 20, 21, 22 show respectively, C. R. S., H. R. S. and Quasi Welds.

Table No. 2 records the physical characteristics of the above welds.

Cast Iron.

Welding.

The welding of cast iron presents greater difficulties than the welding of steel, owing to the weak structure of the material, its brittleness, the presence of many injurious elements and large quantities of free carbon. Furthermore, since the material deposited is usually pure iron having a different coefficient of expansion from that of cast iron, serious strains develop which often produce cracks in the weld or at the junction of the materials.

It is conceded that unless a cast iron weld is annealed it cannot be machined. Undoubtedly considerable advance can be made in cast iron welding, particularly in decarbonizing the cast iron surface by preheating in an oxidizing flame and in the selection of a suitable electrode material giving the proper filler characteristics.

With the knowledge at present available no great reliance can be placed on the production of cast iron welds. When the purpose is essentially that of filling and the material is to be but slightly stressed the use of the process is legitimate.

In general it may be observed that fair welds are produced with Roebling electrodes or by melting C. I. rods with the aid of the carbon arc.

Deposits of Norway or Roebling electrodes on gray cast iron usually exhibit blow holes in the filler and porosity at the junction of the two metals. The structures show a change from cast iron, high in combined and graphitic carbon, to a hard high carbon steel at the weld boundary. During the fusion of the deposited material to the cast iron and its cooling some of the free carbon reduces the oxide slag forming pockets of CO or CO_2 and the remaining carbon permeates through the filler, tending to produce a low grade of hard cast steel.

A close examination of such deposits is apt to reveal in addition to the slag content and porosity, numerous cracks in filler and in the line of fusion between the filler and cast iron.

Curves Nos. 3, 4 and 5 give the rate of cutting cast iron used in which the grip was shunted by a cable, nevertheless, the maximum continuous operating period was but 8½ minutes. The time shown in curves does not include time taken to cool holder or rest operator.

SECTION E

(1) MICROPHOTOGRAPHS OF WELDS AND (2) SUNDRY TABLES

Fig. 1

Section through welded bar, scarf angle 60°, showing shank metal at the left and deposited metal from welding electrode at the right. Illustrating poor fusion throughout lower section of weld obtained due to not separating weld shanks and to use of small scarf angle.

Fig. 2

Illustrating excellent fusion obtained with conditions same as in Fig. 1 excepting weld shanks separated ⅛ inch at bottom, thereby rendering scarf faces more accessible.

Fig. 3

Fusion obtained with plates scarfed to 90°. Section at the left shows character of deposited material, while the adjacent view illustrates the fusion between deposited material (left) and weld shank as well as irregular recession from original straight scarfed face due to high temperature attained during fusion. The light zone in shank metal adjacent fusion line indicates structural change produced by heat treatment during welding operation.

Fig. 4

Compact, well fused deposit obtained with 125 amperes arc current on maintaining a short arc length (22 volts).

Fig. 5

Diffused, poorly fused deposit obtained with 125 ampers arc current when using a long arc (38 volts).

Fig. 6

Top view of section shown in Fig. 4, illustrating smoothness and regularity of deposit.

Fig. 7

Top view of section shown in Fig. 5 showing surface porosity, prevalence of oxide globules and wide as well as irregular deposition of material characteristic of long arc operation.

Fig. 8

Section through good weld showing fracture through deposited material at top, freedom from porosity and slag, excellent fusion at scarf face (90° total angle) and zone of adjacent shank metal modified by thermal changes. Welding current approximately 160 amperes, section of bar 1″ x 1″.

Fig. 9

Section through poor weld due to low arc current, 115 amperes, showing failure, at top, along face of scarf, slag and porosity of deposited material and incomplete fusion with shank metal.

Fig. 10

Top view of polished section of deposit formed with bare electrode showing slight pitting.

Fig. 11

Same as Fig. 10 except reduced pitting obtained on using covered electrode.

5-1 5-2 6-1 6-2 7

Fig. 13

Negligible effect of striking an arc on the strength and ductility of mild steel standard test pieces.

Test Piece	5—1	5—2	6—1	6—2	7
Ultimate Tensile Strength Lbs. per square inch	49,200	49,100	48,400	48,600	49,350
Per cent Elongation	43	41.7	41.8	44	49

Fig. 12 f

Sequence of Metallographic Structures encountered on passing from plate through zone of fusion into deposited metal.

(a) Appearance of sequence enlarged five diameters. Zone 1 showing unchanged plate and Zone 5 deposited metal.

(b), (c), (d), (e), (f) show respectively zones 1, 2, 3, 4, 5 enlarged to 50 times original size

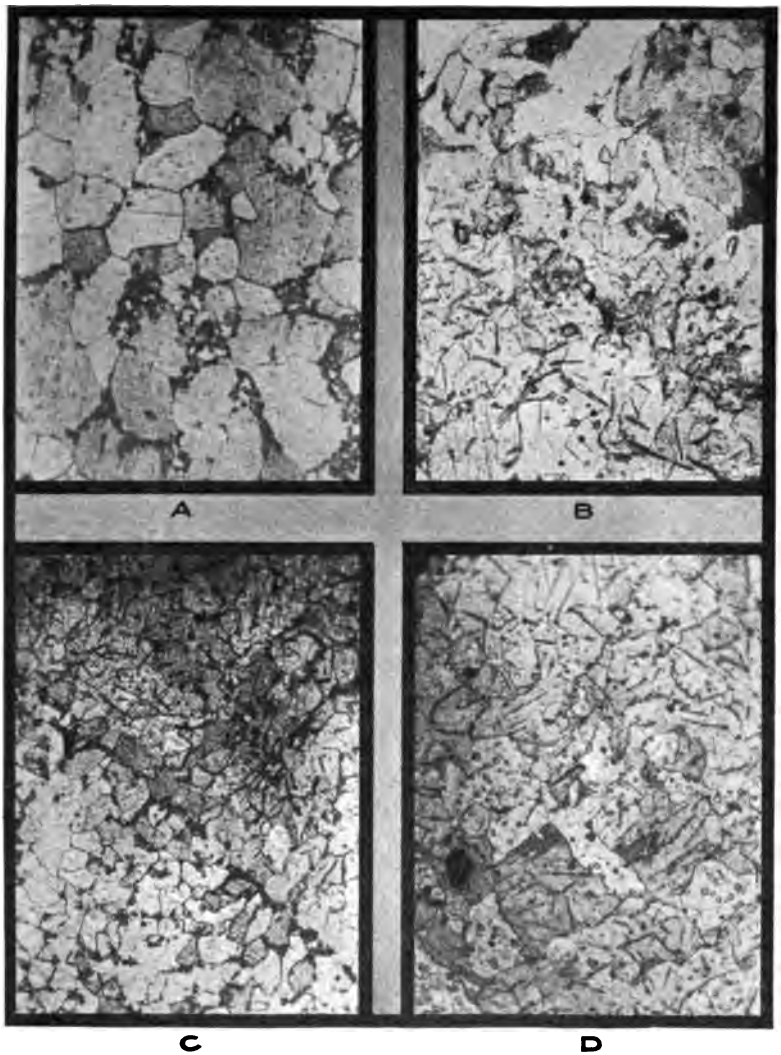


Fig. 14

A. Metal of Original Bar (Figs. 8 and 9) magnified to 400 diameters.

B. Section at Junction of Original Bar and deposited Metal of Fig. 8 magnified to 400 diameters showing complete fusion.

C. Section at Junction of Original Bar and deposited Metal of Fig. 9 magnified to 400 diameters showing poor fusion.

D. Section of deposited Metal shown in Fig. 9 magnified to 400 diameters showing presence of slag, oxide and cementite needles or plates.

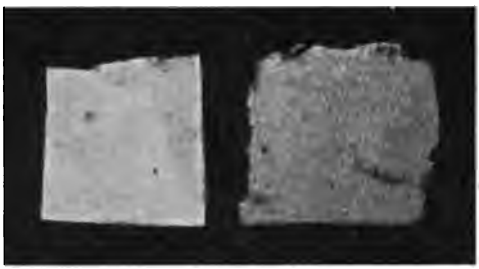


Fig. 15

Character of Fusion and Deposited Metal obtained with bare electrode having—16 C., 56 Mn. (See Tables number 2 and 3).

Fig. 16

Appearance of Deposited Material and welded sections when using Norway Iron Electrodes. (See Tables number 2 and 3).

Fig. 17

Character of Weld Sections obtained when welding with carbon electrode and Norway Iron Filler Rod. (See Tables number 2 and 3).

Fig. 18

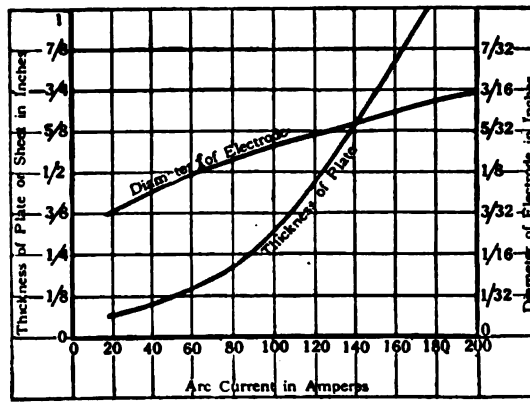
Weld Sections obtained when using Cold Rolled Steel Electrodes. (See Tables number 2 and 3).

Fig. 19

Weld Sections obtained on using Hot Rolled Steel Electrodes. (See Tables number 2 and 3).

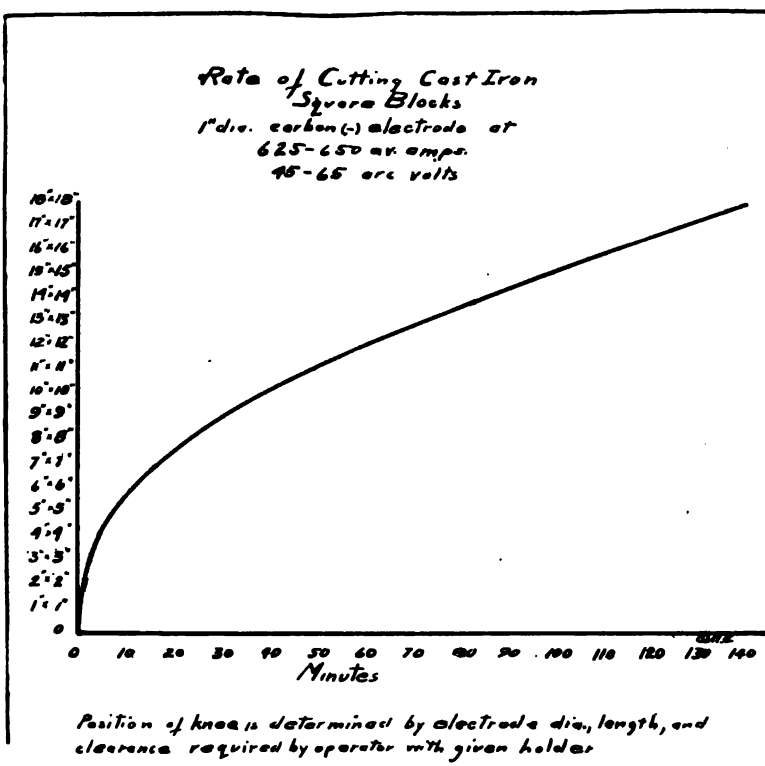
Fig. 20

Characteristic Slag Inclusions obtained when welding heavy sections with covered electrodes. (See Tables number 2 and 3).



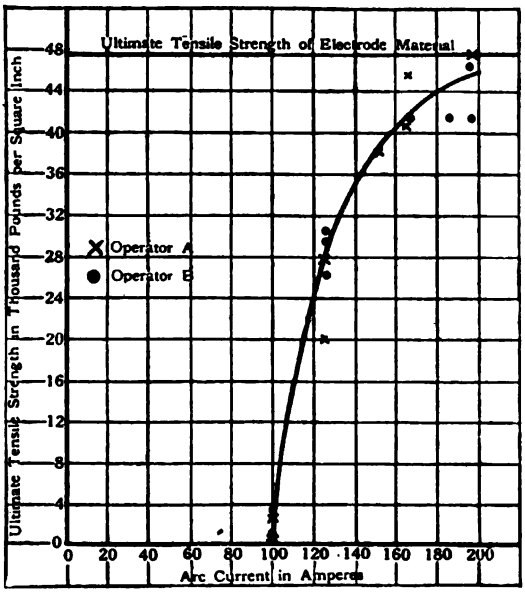
1

Approximate electrode sizes and arc currents for various thicknesses of mild steel plates.

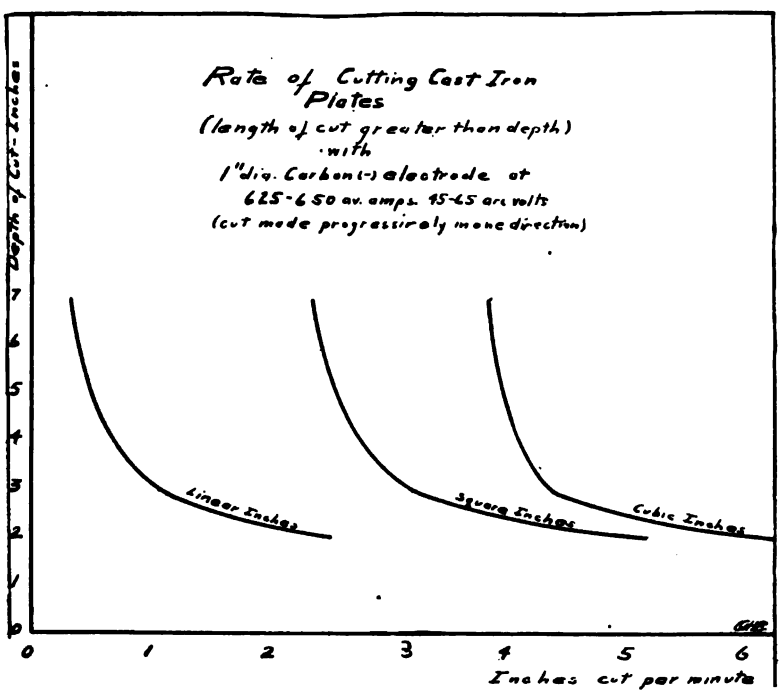


4

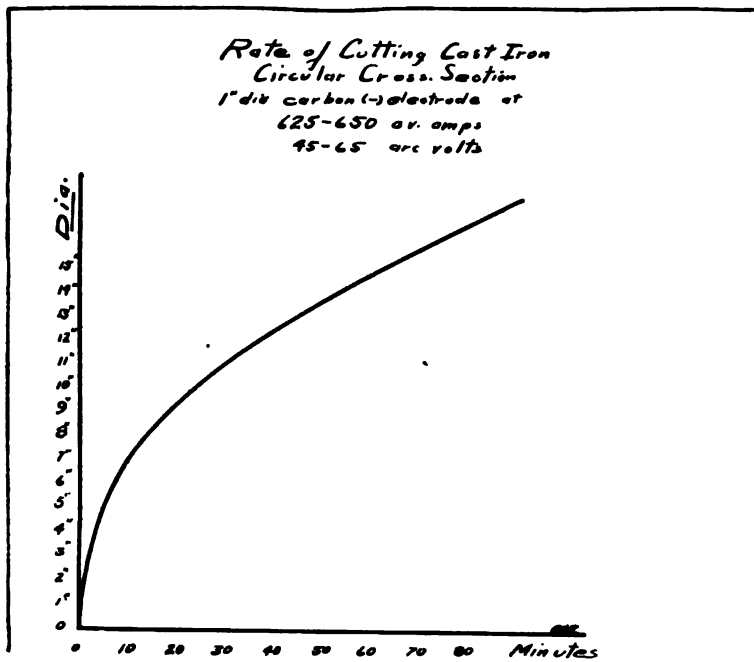
Rate of Cutting Square Cast Iron Blocks.
(Does not include time required to cool electrode holder or rest operator.



2
Change in weld strength with change in welding current.


Rate of Cutting Cast Iron Plates
(length of cut greater than depth)
with
1" dia. Carbon (-) electrode at
625-650 av. amps. 45-65 arc volts
(cut made progressively one direction)
Linear Inches
Square Inches
Cubic Inches
Inches cut per minute
0 1 2 3 4 5 6

3
Rate of Cutting Cast Iron Plates with Carbon Arc.
(Does not include time required to cool holder or rest operator).



5

Rate of Cutting Circular Sections of Cast Iron.
(Does not include time required to cool electrode holder or rest operator.)

TABLE No. 1.
Approximate Arc Current and Electrode Diameter for Welding Various Thicknesses of Low Carbon Steel Plates.

Thickness	Current	Pencil Diameter
1/16"- 1/8"	20- 50	3/32"-1/8"
1/8"- 1/4"	50- 90	1/8"
1/4"- 1/2"	90-125	1/8"-5/32"
1/2"- 3/4"	125-150	5/32"
3/4"-1"	150-175	5/32"-3/16"
Above 1"	175-200	3/16"-7/32"

TABLE No. 2.
Strength of Welded Hot Rolled Steel Plate.

Plate Thickness—1".
" Width—5".
" scarfed to 90°, sections separated 1/8". Tests made on 7/8" square bars and standard 1/2" diameter test bars cut from each weld.

Fig.	Electrode Description	Dia.	Current	Ult. Ten. Lbs. per 7/8" sq. bar	Str. sq. in. 1/2" dia.	1/2" dia. % Elong.	Test Bar % Red.
3	Roebling	5/32"	175	49,660	32,700	3.25	7.0
..	"	5/32"	155	35,350	39,375	5.7	11.5
..	" + borax..	5/32"	155	29,400	22,875	.....	....
15	Roebling ..... (Weld #21)	5/32"	155	.....	48,750	11.3	15.2
16	Norway	.147	180	33,250	24,750	.....	8.5
17	" + ... carbon electrode	....	250	35,000	36,700	5.5	12.6
18	C. R. S.....	3/16"	185	28,000	33,800	3.25	9.7
19	H. R. S.....	1/4"	180	13,400	.....	.....	....
..	"	1/4"	185	25,300	17,875	2.3	3.5
..	"	1/4"	160	10,190	.....	.....	....
20	Quasi	1/4"	185	32,790	27,000	2.2	8.1

TABLE No. 3—ELECTRODE ANALYSIS
Analysis of Plate and Electrode Materials are given in Table #3.

Electrode	C.	Mn.	P.	S.	Si.
Roebling	.16	.56	.032	.024	.016
Norway	.049	.021	.025	.007	.08
C. R. S.....	.11	.72	.097	.123	.011
H. R. S. (Also Plate)	.13-.17	.50	.012	.045	.011
Quasi	.07	.003	.051	.044	.011

CHEMICAL ANALYSIS OF METAL DEPOSITED IN WELD.

Fig.	Electrode Used	C.	Mn.	P.	S.	Si.
3	Roebling	.05	.18	.031	.036	.011
16	Norway	.05	.018	.020	.015	.011
18	C. R. S.....	.05	.11	.086	.072	.011
19	H. R. S.....	.14	.14	.012	.039	.011
20	Quasi	.03	.021	.042	.046	.058

Report No. 17

THE GENERAL ELECTRIC COMPANY'S ACTIVITIES IN ELECTRIC WELDING.

The General Electric Company's Activities in Electric Welding.

As I stated in Report No. 2, I made several visits to some of the plants of the General Electric Company. On most of these occasions I had opportunity to discuss welding with the officials and engineers. The General Electric Company officials arranged for reports to be made for me by their welding specialists in various departments and works.

These reports may be tabulated as follows:

GENERAL HEADINGS.

(A)—Report by Mr. R. E. Wagner, Assistant Manufacturing Superintendent of the Pittsfield works. This report comprises a good deal of information which has been accumulated at Pittsfield on Electric Arc Welding. (Pages 261-296.)

(B)—Report by Mr. E. F. Collins and Mr. P. A. Meyer, both of the Industrial Heating Department of the Schenectady works. (This report comprises descriptions of a number of investigations and machines developed by the Industrial Heating Department. (Pages 297-309.)

(C)—Report by Messrs. J. A. Capp and G. H. Wright, of the Testing Laboratory of the Schenectady works. This report comprises some interesting micrographic studies carried out by Mr. Wright on butt-welds. (Pages 310-319.)

(D)—Report on the subject of spot-welding by Mr. W. L. Merrill of the Power and Mining Department. Mr. Merrill has had charge of a great deal of very important work which has recently been done in the development of spot-welding machinery for heavy plates and for carrying out tests on welds made with such machines. (Pages 320-329.)

(E) Report by Mr. F. W. Caldwell on a method of welding together copper and iron by means of the carbon arc. (Pages 330-331.)

(F)—Report describing an elaborate series of tests made in 1915 to compare the state of the arc welding art at that time. In these tests there were used carbon-arc electrodes, bare-metal electrodes, flux-covered electrodes made by the General Electric Company, flux-covered electrodes made by the Quasi Arc Company of America and also the oxyacetylene process. Cost and quality comparisons of welds made by all of these methods are set forth in this report. (Pages 332-359.)

(G)—Report by Mr. W. I. Delles on apparatus used at the Schenectady works for Instructing Workmen in the Art of Welding. (Pages 360-361.)

SECTION A—CONTRIBUTION BY MR. R. E. WAGNER, ASST. MANUFACTURING SUPT. ELECTRIC WELDING AT PITTSFIELD WORKS.

Practically all the known methods of joining metals together by electric welding processes are employed in the manufacture of apparatus at this plant. This includes spot, butt, line and arc welding.

Spot Welders.

We have six spot welders in almost constant use. The work is done on steel sheets and steel parts varying in thickness from .014" to .375". Time of welding varies from 250 spots per minute on .014" stock in a motor-driven welder to 10 seconds per spot on .375" stock. The welds are strong and generally reliable.

We have done some special work in spot welding, and sample and descriptions are given in photograph No. 297635 (Page 294) attached. See Fig. No. 2, No. 16, No. 17, No. 18, No. 20. See photograph No. 296911 (Page 288) and No. 297093 (Page 289) for views of these welders.

Butt Welders.

There are two butt welders in almost constant use. They are used primarily for welding end rings to the motor bars for induction motors. Their capacity is 2 volts at 50,000 amperes, 60 cycles. Copper up to .4 square inch is welded and also steel rods 1¼" diameter. Have used this machine for welding high speed steel tips to low carbon shanks for tool work, thus economizing on high-speed steel.

Line Welders.

Several of these have been developed at Pittsfield for use in making line welds on sheet steel in thickness up to .025". The maximum current required in most cases is 4 volts and 5,000 amperes, welding at the rate of 1" per second. These types have a single wheel or multiple wheels running on a fixed bar. The metal to be welded is placed between the wheel and the bar which constitute the terminals of the secondary of the welding transformer.

View of one of these machines is shown in photograph No. 296767 (Page 284), where it is applied to a punch press

and welds the sheets so that a continuous strip passes through the press. Photos also show punchings with welding line across them. It is essential that the sheets, where they overlap one another, be reasonably free from rust and scale. A machine shown in photograph No. 297535 (Page 291) is used to clean edges back about $\frac{1}{16}$". Emery cloth belts rub against edges as the sheet passes through the machine.

Electric Arc Welders.

Electric arc welding with both metallic electrode and carbon electrode are used extensively in the production of transformer tanks. Average production amounts to 20 large boiler plate tanks and 200 large and small corrugated tanks per week.

The welding of boiler plate tanks is done with bare metal electrode and D. C. current at 75 volts. The equipment consists of a 225 H. P. induction motor driving a 150-K.W. 75-volt D. C. generator. Current is taken to two main busses at the switch board where the voltage is held constant by means of a voltage regulator and a curve drawing voltmeter shows the foreman on the work just how his outfit is operating. Any serious irregularity in the voltage supplied adversely affects the welding.

There are 12 welders operating on this set and each welder's circuit originates at the constant potential bus. The positive line passes directly to the welder's panel; the negative line passes through a contactor, overload relay, remote control rheostat, reactance, thence to welder's panel, see photograph No. 297350 (Page 289) for switchboard. Contactor will open if excessive current flows through the circuit, and may also be opened by the operator through the relay.

Capacity of each welder's circuit is 200 amperes.

The single and double panels at the welder's station are fitted with ammeters, push button switches for operating rheostats, and heavy sockets in which the plug on the welding line is inserted when operator is preparing for work. The panels are so connected that when welding lines are plugged in on them, the positive side of the line is connected to the work and the negative side to the electrode. See photograph No. 297643 (Page 296) for welder's station.

The bare metal electrode is used entirely on this work.

The following grades of wire have been found satisfactory for this work:

Toncan wire, Apex wire, made by the Washburn Wire Company, Phillipsdale, R. I.

Armco (American Ingot), Bright (Hard Drawn Welding Wire), made by Page Steel & Wire Co., Monessen, Pa.

Norway and Swedish Irons.

An analysis of wire gives some indication of its applicability to electric arc welding but the crucial test is a trial.

A satisfactory wire will melt and drop small particles uniformly into the weld; if rather large globules drop from the welding rod the weld is apt to be porous and the welding metal poorly united to the metal being joined. The Toncan wire which we have found very satisfactory is a refined open hearth steel and contains the following by analysis:

Carbon .10%
Manganese .16%
Silicon, Trace
Phosphorus .010%
Sulphur .046%

In the application of electric arc welding to the building of boiler plate transformer tanks certain arrangements must be made to properly prepare parts for welding.

Where plates are welded edge to edge or butt-welded the edges should be beveled approximately 30° if the thickness is 3/16″ or greater. Sheets less than 3/16″ thick need not be beveled. Beveling enables the operator to apply the arc to the bottom of the recess to be filled with welding metal and obtain a weld the full depth of the plates.

When welding long seams provision must be made for shrinkage of gap between plates. This is done by expanding gap about 1½% of its length. At the beginning of weld, gap should be about ⅛″ on plates between $\frac{3}{16}$″ and ⅝″ thick, and at the end away from weld, the gap should be 1½% of the length of seam plus ⅛″.

Shells and Bases.

When shells are welded to bases for tanks the plate is beveled as for seams and a gap of approximately ¼″ exists between shell and base on tanks made of plates $\frac{3}{16}$″ and greater. Shells are held with proper gap by means of wedges. Shells are tacked to base in spots all the way around before welding the complete joint is begun. See photograph No. 296585. (Page 280.)

Hoods.

Hoods for welders are made of press board and fitted with a round window 6″ diameter made of 1 piece of plain glass, 1 of medium green glass and 1 of dark red glass. The plain glass is used to protect the colored glass against pitting with molten metal. The colored glass is used to protect the eyes of the welder against intense rays of the arc.

WELDING DATA.

(Actual Observations.)

Rivets.

Three ¾" rivets welded in one end in ⅜" boiler plate in 12 minutes.
5/32" bare wire electrode used.
75 volts—160 amperes—D. C.

See photograph No. 296614-5-6 (Pages 284 and 285) and Micrograph No. 370 (Page 273).
Sixty-six ¾" rivets welded on one end in four hours.
Rivets holding ¾" angle iron band to ⅜" boiler plate.
5/32" bare wire electrode used.
75 volts—140 amperes—D. C.

Sixty-two ¾" rivets welded on one end in four hours.
Rivet holding 1" band to ⅜" boiler plate.
5½ lbs. of 5/32" wire used.
75 volts—140 amperes—D. C.

Locating Pins.

Four 1¾" locating pins in ½" base.
1½ hours—75 volts—150 amperes—D. C.
1½ lbs. of 5/32" wire.
See photograph No. 296589 (Page 282).

Drain Pipe.

1 2" drain pipe in ½" base.
1½ hours. 75 volts—150 amperes.
2 lbs. 5/32" wire.
See photograph No. 296589 (Page 282).

Data on Seam Welds for Regular Production Work.

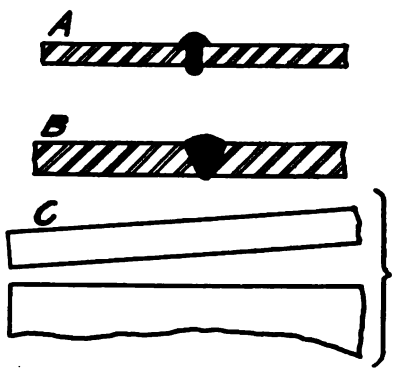
Item No.	1	2	3	4	5	6	7	8
Length in feet	2.5	3.33	14.5	8.75	9.5	6.0	12.0	
Total time hrs.	1.5	1.5	7.5	4.5	*12.	4.	†11.	
Time in min. per straight foot	30.	25.	20.	25.	35.	33.	45.	
Size wire	1/8"	1/8"	5/32"	1/8"	5/32"	5/32"	5/32"	
Lbs. wire per foot of weld	.5	.6	.5	‡.68	1.5	1.33	1.75	
Thickness material	1/8"	1/8"	3/16"	1/4"	3/8"	3/8"	1/2"	
Amperes	70	70	120	130	160	135	180	
Volts	75	75	75	75	75	75	75	

‡6 lbs. of wire were used. There was left ½ lb. of scrap ends.

*Two men on this job for 12 hrs. Hours charged to the job 24.

†Two men on this job for 11 hrs. Hours charged to the job 22.

Above results were obtained by different welders.



(A) General appearance of weld on material less than 3/16" thick.

(B) General appearance of weld on material 3/16" to 5/8" thick.

(C) General appearance of seam prepared for welding. Approximately 1/8" gap at the start and increased about 1½% of its length from the start.

Boiler Plate Shells Electric Arc Weld to Steel Bases

Thickness of steel shell	1/8"	1/8"	1/4"	1/4"	3/8"	3/8"	3/8"	3/8"	1/2"
Thickness of base	1/8"	1/4"	1/4"	3/8"	3/4"	3/4"	3/4"	3/4"	5/8"
Size of electrode wire	1/8"	1/8"	5/32"	5/32"	3/16"	3/16"	3/16"	3/16"	5/32"
Amperes	70	110	120	160	180	160	170	160	160
Volts	75	75	75	75	75	75	75	75	75
Time to weld one straight foot inside	—	—	15′	14′	15′	—	—	—	—
Time to weld one straight foot outside	—	—	15′	25′	25′	—	—	—	—
Time to weld total distance inside—hrs.	—	2.5	3	3	9	14	15	15	25.5
Time to weld total distance outside—hrs.	1.6	2.5	3	6	22	34	34	38	—
Distance around the tank	7′	15′	7′	10½′	30′	38.5′	38.5′	40′	31.7′
Pounds wire used inside	—	2	2½	—	20	14	16	—	60
Pounds wire used outside	2	2.5	2½	—	35	43	44	—	0
Sketch	V	III	III	I	II	II	II	II	IV
Gap between shell and base	—	—	1/8"	3/16"	3/16"	3/16"	3/16"	3/16"	3/16"

Energy cost 1c per KW. hour.

Tubes.

Following results were obtained welding 2½" tubes in ¼" boiler plate.

Tubes project through boiler plate ⅛" are expanded and lips turned over to make an angle of approximately 30° with surface of plate.

See photograph No. 296584. (Page 281.)

Time required to weld 1 tube end—5 min.

Time required to weld 10 tube ends—1 hr.

Time required to weld 200 tube ends—24 hrs.

Thickness of tube wall .094".

Size of electrode 5/32" dia.

Current required—75 volts—160 amp. D. C.

See photograph 296102 (Page 278). See also sketch with micro-photo No. 315. (Page 272.)

Caulking.

Caulking by electric welding, joint between ¾" angle iron band and ⅜" shell of tank.

Total distance around tank 36'6".

Time to weld, 9 hrs.

Electrode 5/32" dia.

Current—75 volts—140 amps. D. C.

Average Results of Strain Tests.

Size of samples 2"x¼".

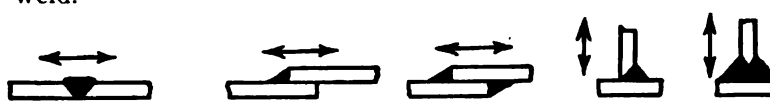
No. I Butt Weld—Breaking Strain 22150# in weld.

No. II Lap Weld one side Breaking Strain 23000# in weld.

No. III Lap welded 2 sides Breaking Strain 31300# outside weld.

No. IV Angle Weld 1 side Breaking Strain 21000# in weld.

No. V Angle Weld both sides Breaking Strain 30500# in weld.



We are producing a great many corrugated steel tanks that have seams electrically welded with the carbon arc. The methods of doing this work and the results obtained are shown in photograph No. 296613 (Page 285), No. 297351 (Page 290).

The electrical equipment for this work is an exact duplicate of that described for the metallic electrode welders.

The corrugated sheets are joined by welding together upturned edges of the sheets. See 6-A in photograph No. 297635. (Page 292.)

The arc is applied by means of a moulded tapered carbon pencil which is ½" at the large end and tapers to ⅛" in its length of 6". This form serves to concentrate the arc at the point required. No metal is supplied to the weld, the arc being used simply to fuse the upturned edges together. This process is applied to metal ⅛" and 3/32" thick.

Speed of welding ⅛" stock by hand is 2.4 inches per minute, with current of 35 amperes at 75 volts D. C.

Speed of welding ⅛" stock with machine is 5.5 inches per minute, with currents of 45 amperes and 75 volts D. C.

Speed of welding 3/32" stock by hand is 2.2 inches per minute, with current of 50 amperes and 75 volts D. C.

Speed of welding 3/32" stock with machine is 5.5 inches per minute, with current of 70 amperes and 75 volts D. C.

The metallic electrode arc welding has been applied to production work for three years and the carbon electrode arc welding has been applied for 12 years. Our experience with both methods has been entirely satisfactory.

Other forms of electric welding have also proven highly satisfactory from standpoint of costs and results obtained.

DATA ON HARDNESS OF ELECTRIC ARC WELD.

Following tests were made on metal deposited with oxy-acetylene flame and with electric arc. Tests were made in the laboratory with a Shore Scleroscope using the magnifier hammer. Welds were made on boiler plate.

	Gas		Electric Arc	
	Boiler Plate	Weld Metal	Boiler Plate	Weld Metal
	69	62	71	70
	67	66	72	70
	68	63	76	73
	74	68	77	70
	73	65	82	72
	70	65	78	68
	68	67	72	72
	68	67	70	66
	71	69	75	67
		70	77	72
	—	—	—	—
Av.	69	66	75	70

Tests made December 11, 1915.

Comparative Costs Between Acetylene and Arc Welding.

In the accompanying table are given some interesting data comparing the cost of electric arc welding with acetylene. These figures, which were based on tests made with a Lincoln welding machine, are based on the following costs:

Acetylene	1 cent per cubic foot.
Oxygen	2 cents per cubic foot.
Electricity	2 cents per kilowatt-hour.
Labor	30 cents per hour.

In the small sizes of metal, the speed of acetylene welding is greater than that of electric, while in the large sizes, the speed of electric welding is much greater. The calorific value of acetylene is 1,555 British thermal units per cubic foot. One kilowatt-hour is equivalent to 3,413 British thermal units.

Comparative Cost Data—Acetylene and Electric Welding.

Tip No.	Thickness of metal	Cu-ft. per hour Acetylene	Cu-ft. per hour Per hr. Oxygen	Ft. Weld per hr.	Cost of Gas	Total cost per Hour	Cost per. ft. Welded
1	1/32"	3.21	3.65	30	$.11	$.40	$.013
2	1/16"	4.84	5.50	25	.16	.46	.018
3	3/32"	8.14	9.28	20	.27	.57	.028
4	1/8"	12.50	14.27	15	.40	.70	.047
5	3/16"	17.81	21.32	9	.61	.91	.101
6	1/4"	24.97	28.46	6	.82	1.12	.187
7	5/16"	33.24	37.90	5	1.09	1.39	.278
8	3/8"	41.99	47.87	4	1.38	1.68	.420
9	1/2"	57.85	65.95	3	1.90	2.20	.733
10	5/8"	82.50	94.05	2	2.71	3.01	1.510

Tip No.	Amperes in Arc	K.W. Input M-G Set	Cost of Power	Ft. Weld per hr.	Total Cost per hr.	Cost per ft. welded
1	70	3.00	$.06	25	$.36	$.014
2	75	3.08	.06	20	.36	.018
3	80	3.20	.06	15	.36	.024
4	90	3.52	.07	10	.37	.037
5	110	4.15	.08	8	.38	.048
6	110	4.15	.08	8	.38	.048
7	120	4.64	.09	7	.39	.056
8						
9	150	5.75	.12	6	.42	.070
10	150	5.75	.12	6	.42	.070

INFLUENCE OF CURRENT ON ARC WELDS.

Mr. O. A. Kenyon, of the Arc Welding Machine Company, has published the following results:

"To study the effect of current on the strength of weld and penetration of fusion, I made tests with three types of joints, shown in the illustration, and welded each of these joints with 80, 90, 100, 110, 120 and 130 amp. The pieces were welded as near flush as possible and machined to the thickness of the plate before pulling. The table gives the results of the tests which were made by the Pittsburgh Testing Laboratories. In

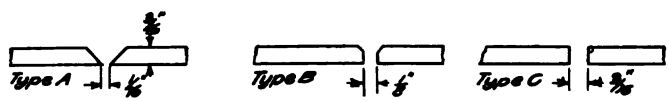
the full bevel where the arc played directly on the surface the welds were better than the original material. In the half bevel and square joints the low currents failed to cause sufficient penetration to fuse the thick edges of the joint through the full section, and therefore some of these broke at the joint; while where the current was sufficient to fuse through they all broke outside of the joint."

Results of Pulled Tests on Welded Specimens.

Test	Type	Amp.	Yield Strength lb. per sq. in.	Breaking Strength lb. per sq. in.	Location
1	A	80	31,540	51,040	Material
2	A	90	45,400	59,440	Material
3	A	100	41,790	54,680	Material
4	A	110	45,500	59,770	Material
5	A	120	34,790	56,310	Material
6	A	130	42,490	56,190	Material
7	B	80	37,700	57,590	Weld
8	B	90	32,290	51,440	Weld
9	B	100	29,000	40,790	Weld
10	B	110	43,910	43,830	Weld
11	B	120	30,940	49,650	Material
12	B	130	32,430	51,980	Material
13	C	80	31,170	49,840	Weld
14	C	90	39,580	40,690	Weld
15	C	100	43,130	57,270	Material
16	C	110	31,960	52,800	Weld
17	C	120	41,780	57,120	Material
18	C	130	39,160	57,780	Material
37	A	Gas	28,360	38,390	Weld
38	B	Gas	.....	38,260	Weld
39	C	Gas	34,200	50,310	Weld

Diagrams to illustrate effect of current on welding different types of joints:

Type A. Type B. Type C.



Weld Joint of Steel Tubing and Boiler Plate Steel, made by electric welding. With a cavity present at junction of weld.

Magnification 35 No. 314.

1 Tubing, 2 Boiler Plate Steel. Etched. 3 Norway Iron.

Magnification 35 No. 315

Weld Joint of Steel Tubing and Boiler Plate Steel, made by electro-welding. With no cavity present at junction of weld. 1 Tubing, 2 Boiler Plate Steel. Etched. 3 Norway Iron.

Magnification 79 No. 316

Weld Joint of Steel Tubing and Boiler Plate Steel, made by electric welding. Same as No. 314 but taken at a higher magnification. 1 Tubing, 2 Boiler Plate Steel, 3 Norway Iron. Etched.

Magnification 220 No. 317

Weld Joint of Steel Tubing and Boiler Plate Steel, made by electric welding. Same as No. 315, though taken at a higher magnification. 1 Tubing, 2 Boiler Plate Steel, 3 Norway Iron. Etched.

Magnification 57 No. 318

Shaped Weld-Joint of Boiler Plate Steel made by electro-welding. Taken along one of the two lines of weld. The large black spots are cavities presenting joints. 1 Norway Iron, 2 Boiler Plate Steel. Etched.

Magnification 100 No. 319

Shaped Weld-Joint of Boiler Plate Steel made by electro welding. Taken along the other line of weld (See No. 318) and at a higher magnification. 1 Norway Iron, 2 Boiler Plate Steel. Etched.

Magnification 100 No. 370

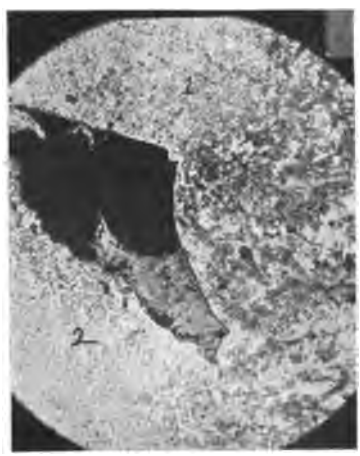
Riveted and Electric Welded Boiler Plate Steel showing that a good weld had been formed between rivet head and iron weld. Line of weld runs along the two differently shaded areas.

No. 314

Weld-Joint of Steel Tubing and Boiler Plate Steel, made by Electro-Welding. With a Cavity Present at Junction of Weld. 1-Tubing. 2-Boiler Plate Steel. 3-Norrway Iron.

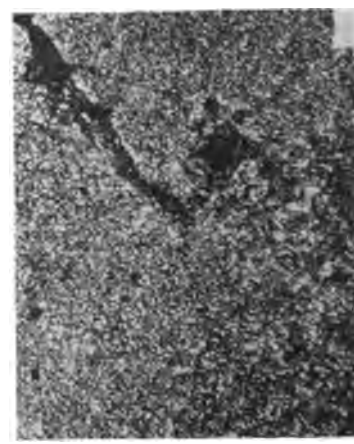
No. 315

Weld-Joint of Steel Tubing and Boiler Plate Steel, made by Electro-Welding. With no Cavity at Junction of Weld. 1-Tubing. 2-Boiler Plate Steel. 3-Norway Iron.



No. 316

Weld-Joint of Steel Tubing and Boiler Plate Steel, made by Electro-Welding. Same as No. 314, Though Taken at a Higher Magnification. 1-Tubing. 2-Boiler Plate Steel. 3-Norway Iron.



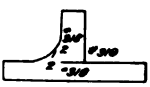
No. 317

Weld-Joint of Steel Tubing and Boiler Plate Steel, made by Electro-Welding. Same as No. 315 but Taken at a Higher Magnification. 1-Tubing. 2-Boiler Plate Steel. 3-Norway Iron.

No. 318

⊥ Shaped Weld-Joint of Boiler Plate Steel, made by Electro-Welding. Taken Along one of the two Lines of Weld. The Large Black Spots are Cavities Present in Welded Joint. 1-Norway Iron. 2-Boiler Plate Steel.

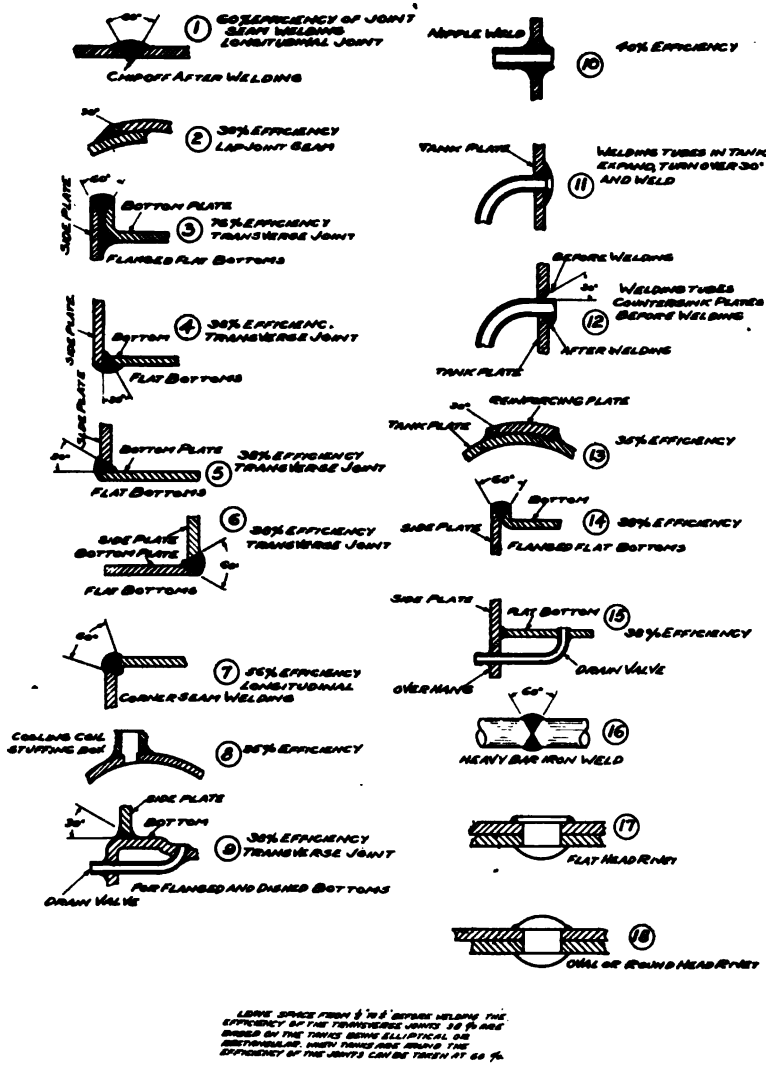
No. 319



⊥ Shaped Weld-Joint of Boiler Plate Steel made by Electro-Welding. Taken Along the other Line of Weld (See No. 318) and at a Higher Magnification. 1-Norway Iron. 2-Boiler Plate Steel

No. 370

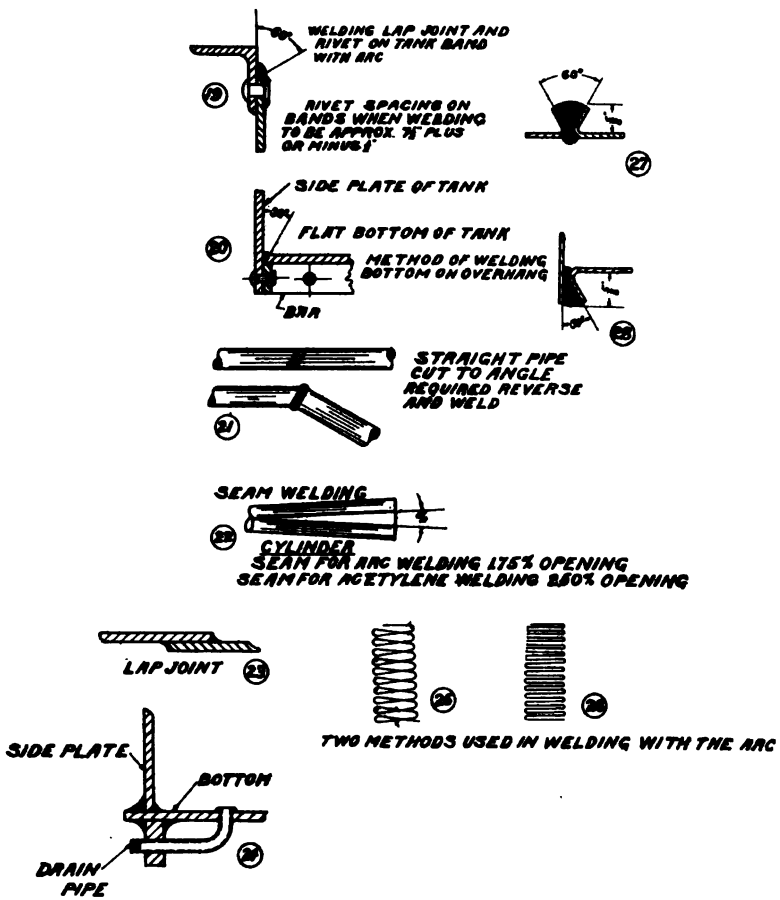
Riveted and Electric-Welded Boiler Plate Steel. Showing that a Good Weld had been Formed Between Rivet Head and Iron Weld Line of Weld runs Along the two Differently shaded areas.



LEAVE SPACE FROM $\frac{1}{2}$" TO $\frac{5}{8}$" BEFORE WELDING THE EFFICIENCY OF THE TRANSVERSE JOINTS 38 & 80 ARE BASED ON THE TANKS BEING ELLIPTICAL OR RECTANGULAR. WHEN TANKS ARE ROUND THE EFFICIENCY OF THE JOINTS CAN BE TAKEN AT 60 %.

P-599254

SEAMS—Acetylene & Arc Welding


WELDING LAP JOINT AND RIVET ON TANK BAND WITH ARC
RIVET SPACING ON BANDS WHEN WELDING TO BE APPROX. 75" PLUS OR MINUS 1"
60°
SIDE PLATE OF TANK
FLAT BOTTOM OF TANK
METHOD OF WELDING BOTTOM ON OVERHANG
BAR
STRAIGHT PIPE CUT TO ANGLE REQUIRED REVERSE AND WELD
SEAM WELDING
CYLINDER
SEAM FOR ARC WELDING 175% OPENING
SEAM FOR ACETYLENE WELDING 250% OPENING
LAP JOINT
TWO METHODS USED IN WELDING WITH THE ARC
SIDE PLATE
BOTTOM
DRAIN PIPE

P-599254 (continued)

SEAMS—Acetylene & Arc Welding

VOLTS, AMPS. AND POINTS AND DIA. OF WIRE USED ON DIFFERENT THICKNESSES OF METAL.

		Volts.	Amps.	Pts.	Wire.
Welding	½" Seam.....	75	150	29	1/16"
"	3/8" "	75	140	28	1/16"
"	1/4" "	75	110	25	5/32"
"	1/16" "	75	85	21	5/32"
"	1/8" "	75	75	18	5/32"
"	½" Base to 3/8" Shell.....	75	160	28	1/16"
"	½" " " 1/4" "	75	130	26	1/16"
"	1¾" Locating Pins to ½" Base	75	140	27	1/16"
"	Stuffing Boxes to 3/8" Shell	75	145	28	5/32"
"	" " " 1/4" "	75	125	26	5/32"
"	5/32" Tubes to 3/8" Shell....	75	120	25	5/32"
"	5/32" " " 1/4" "	75	100	23	5/32"
"	3/8" Shell to 5/8" Bottom..	75	165	31	1/16"
"	5/32" Tube to 5/8" Flange...	75	140	28	5/32"
"	1/16" Base to 1/16" Shell....	75	110	25	5/32"
"	1¼" Band to 3/8" Shell....	75	150	29	1/16"
"	Drainpipe to ½" Shell....	75	135	27	1/16"
"	Rivets to 3/8" Shell.....	75	130	26	5/32"
"	1/16" Seam	75	40	9	5/32"
"	3/4" "	75	160	27	1/16"
"	1" "	75	170	32	1/16"
"	1¼" "	75	155	29	1/16"
"	(Calkweld) 1" Bar to 3/4" Plate	75	140	29	5/32"
"	(Calkweld) 1¼" Band to 3/8" Plate	75	150	..	5/32"

6 inch Standard Wrought Iron Pipe After Test at 1000 lbs. One Cap and Seams Welded with the Electric Arc.
192689

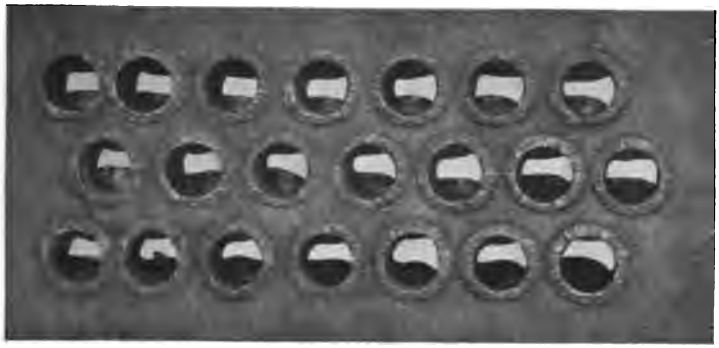
8 inch Standard Wrought Iron Pipe After Test at 800 lbs. Pressure One Cap and Seams Welded with the Electric Arc.
192690

Plating Tank and Radiator Electric Arc Welded Tank 96 in. by 36 in. by 24 in.—¼ in. Stock ¼ in by 1-½ in. Angle Iron.
296086

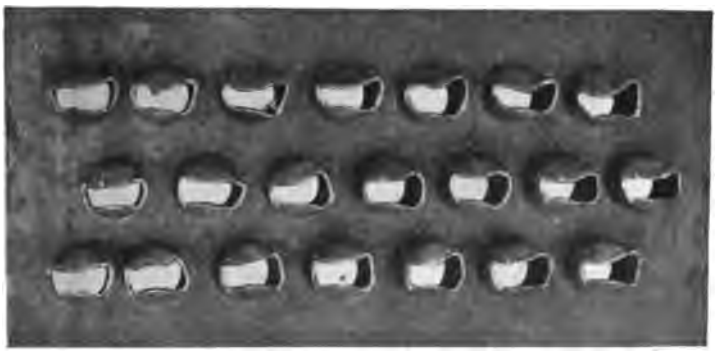
296100

Tubular Transformer Tank Showing Inner View of Tubes.
Electrically Arc Welded to Boiler Plate.
296102

Tubular Transformer Tank. Base, Tubes, Etc., Welded by Electric Arc Welding Process.
296103



296167. 2 in. Tubes Electric Arc Welded in ¼ in. Boiler Plate Showing Welds and Battered Tubes. No Oil Leaks Produced.



296168. 2 in. Tubes Electric Arc Welded in ¼ in. Boiler Plate Showing Battered Tubes. No Oil Leaks Produced.

296237. Tanks with Seams, Bottoms and Outlets Welded by Electric Arc Welding Process.

296288. Section of a Smoke Stack, Seams Welded by Electric Arc Welding Process. Metal ¼ in. Boiler Plate

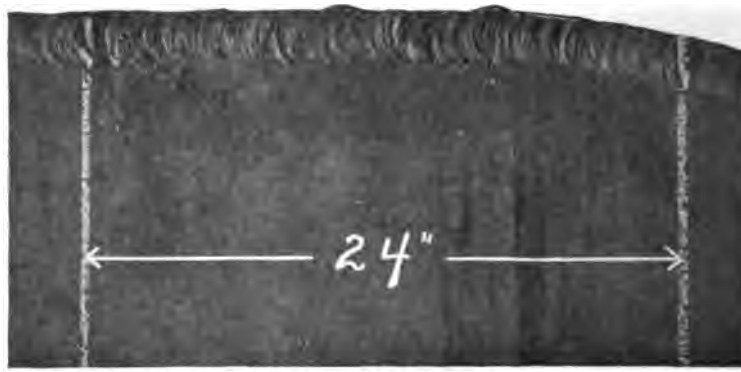
296583. Tank with Electric Arc Welded Seam, Surface Weld Ground Off to Present a smooth Appearance. Weld Reinforced On Inside.

296585. Base of Tank Prepared for Electric Arc Welding, Note Gap at Base and Spot Welds Tying Base and Shell Together.

296584. Tubes Expanded Preparatory to Electric Arc Welding.

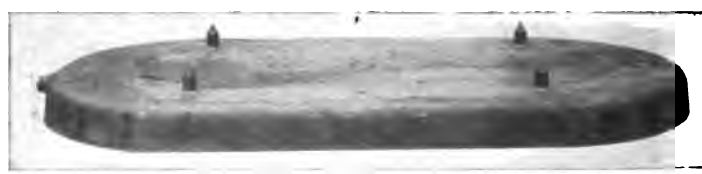
296586. Inside View of Seam in Electric Arc Welded Tank Showing Metal Forced Through Seam and Reinforcing at End of Seam.

296587. New View of Electric Arc Weld in Bottom of Tank, ¾ in. Base, ⅜ in. Shell Metal, Size 77 in. x 144 in. x 168 in. High.



Closer View of 296587

296588. Bottom of Tank Showing Electric Arc Weld, ⅛ in. Shell, ¼ in. Base Metal, Tank Size 22⅝ in. x 25⅜ in. x 19 in. High.



296589. Locating Pins Electric Arc Welded in Base for Tank.

296590. Electric Arc Welded Base on Tank, ⅜ in. Shell, ¼ in. Base Metal, Size of Base 61 in. x 142 in.

296591. Electric Arc Welding Seam in Tank, Note Preparation of Seam and Method Employed to Maintain Proper Gap.

296592. Applying Hammer Tests to Electric Arc Welded Joints.

296611. Electric Arc Welded Tank for Holding Hot Oil, Rim made of ½ in. Boiler Plate, Tank of $\frac{3}{16}$ in. Plate Size of Tank 15 in. x 30 in. x 21 in.

296614. Rivets Sealed with Electric Arc Welding, Metallic Electrode.

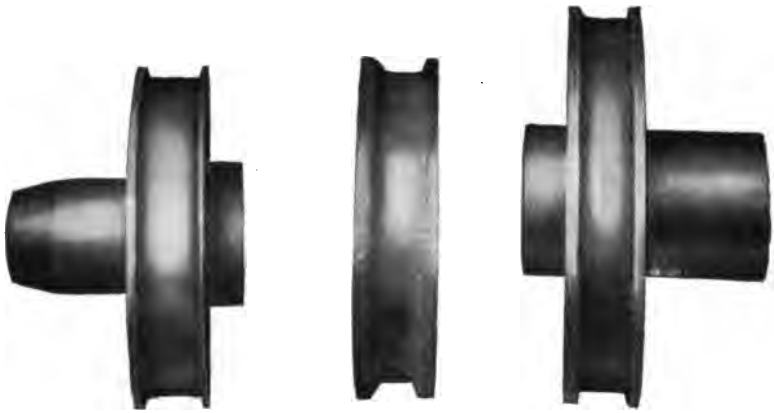
296613. Preparation of Seam in Corrugated Sheet Steel for Electric Arc Welding with Carbon Electrode.

296615. Rivets Sealed with Electric Arc Welding, Metallic Electrode.

296616- Two Pieces of Boiler Plate with Loose Rivets, River Electric Arc Welded about Head and Tail and made Oil Tight.

296683. Steam Plate for Hydraulic Press Showing Electric Arc Weld. Two ¾ in. Steel Plates held with Keys and Welded. Size Plate 40 in. x 40 in.—150 lb. Steam Pressure.

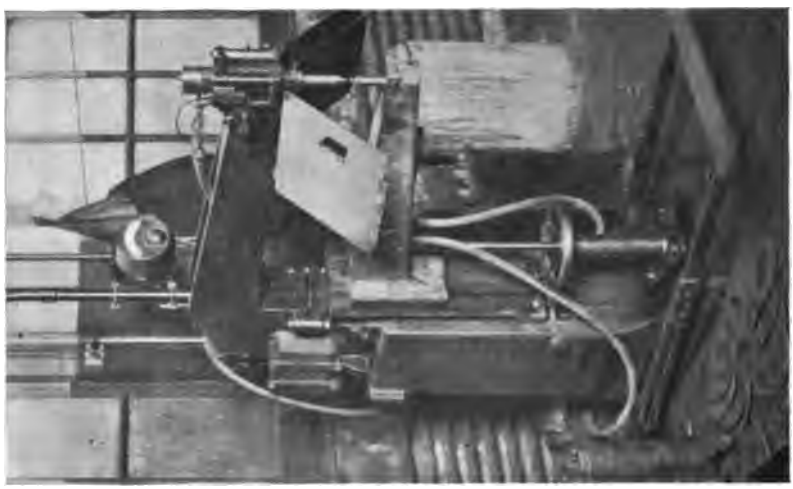
296767. Electric Welding Machine for Welding Transformer Iron. Equipped with Automatic Feed; Together with Punch Press.]



296809. Worn Crane Wheel Flanges Repaired by Electric Arc Welding Process.

296872. Transformer Cover Showing Flanges Rivets and Nipples Sealed with Electric Arc Welding

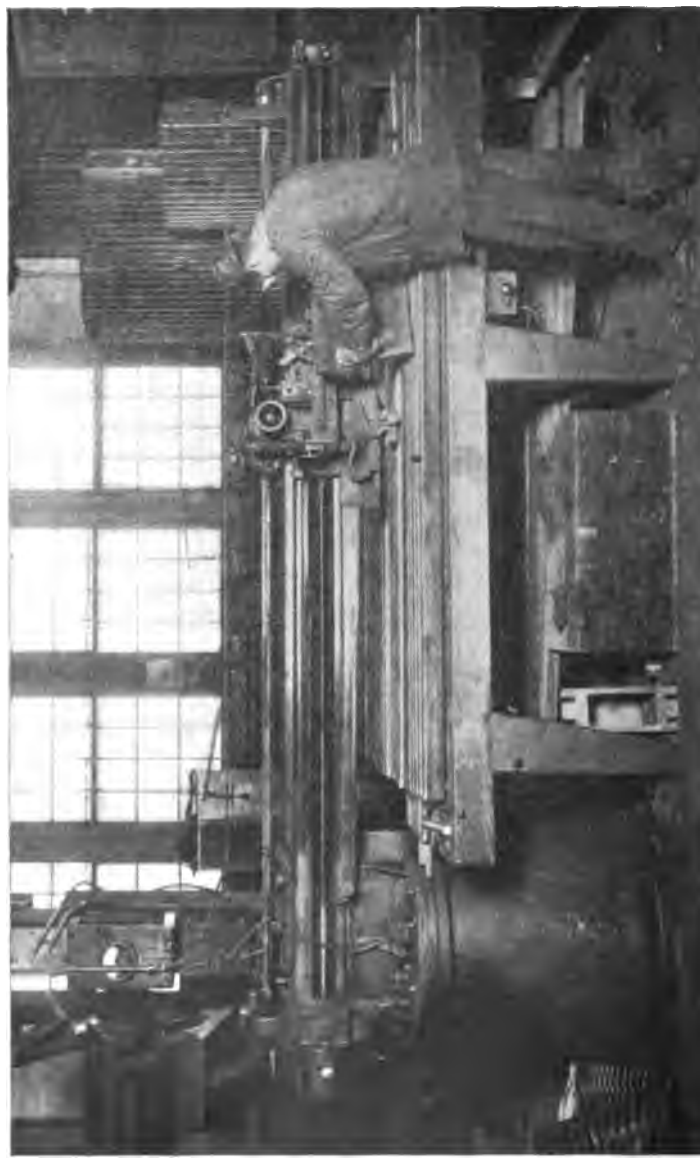
297006. Conservator Tank for use on Transformer for Holding Oil. Made from Boiler Plate with Seams Welded by Electric Arc Process.



296911. Spot Welder Showing Adjustable Guards that Prevent Sparks Flying Laterally from Welding Points.

297093. Thomson 20A Spot Welder Showing Cooling Fixture on Electrode.

297350. Switchboard, Rheostats, Motor Generator Set for 12 Electric Arc Welders



297351. Electric Arc Welding Machine, Used for Welding Corrugated Steel Tanks 116 in. Long.

297535. Edge Grinder for Transformer Core Plate Stock.

297405. Electrically Welded Oil Switch Tank. Thickness of Metal $\frac{1}{8}$ in.

ATTACH TO PHOTOGRAPH No. 297635.

No. 1—Tube made from $\frac{1}{16}$" steel. Lap weld. Electric arc weld. Bare electrode, $\frac{1}{16}$" dia. Welding current 75 volts, 30 amp. D. C. Speed of welding, 30" in 7 minutes. Base $\frac{1}{16}$" welded. Kerosene test showed no leaks. Dia. tube 1½".

No. 2—Spot weld. 11 pieces .040" sheet steel welded together. Resistance weld. Welding current 4 volts, 2,500 amp., 60 cycles. Time, 3 minutes per spot.

No. 3—Electric arc weld. ¼" boiler plate. Edge of plates beveled 30° and separated $\frac{1}{16}$". Seam in a vertical position when welded. Welding current 75 volts, 110 amp. D. C. Bare electrode 5/32" dia. Length of weld, 10". Time required, 7 minutes. Kerosene test showed no leaks. Break strain **33,000** lbs. in the weld, per square inch.

No. 3A—Section of No. 3.

No. 4—Electric arc weld. ⅜" boiler plate. Edge of plates beveled 30° and separated $\frac{1}{16}$". Seam in an overhead position when welded. Welding current 75 volts, 135 amp. D. C. Bare electrode 3/16" dia. Length of weld 7". Time required, 7 minutes. Kerosene test showed no leaks. Break strain **51,000** lbs. per square inch.

No. 4A—Section of No. 4.

No. 5—Electric arc weld, ¼" boiler plate. Edge of plates beveled 30° and separated $\frac{1}{16}$". Seam in horizontal position when welded. Welding current 75 volts, 105 amp. D. C. Bare electrode 5/32" dia. Length of weld, 10". Time required, 6 minutes. Kerosene test showed no leaks. Break strain, **50,000** lbs. per square inch.

No. 5A—Section of No. 5.

No. 6—Electric arc weld, $\frac{1}{16}$" sheet steel. Edges turned up and welded. Welding current, 75 volts, 30 amp. D. C. Speed of welding, 2" per minute. Hand welding. Carbon pencil electrode used.

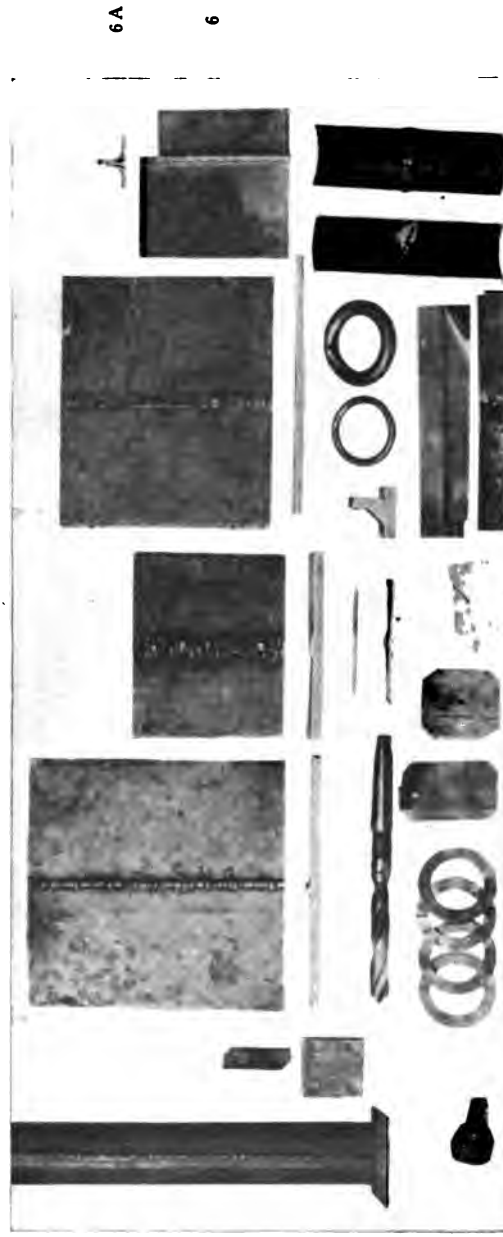
No. 6A—Section of No. 6.

No. 7—Reclaimed $\frac{5}{8}$" drill. Was broken at shank. Electric arc welded with carbon pencil electrode. 75 volts, 70 amp. D. C. Speed of welding, 3 minutes. Has not failed after two months' service.

No. 8—⅛" steel shank butt welded to threaded stem. Welding current 2 volts. 800 amp., 60 cycles. Time required, 1 second.

No. 9—⅛" sheet steel. Electric arc weld. Edges butted with 1/32" gap. No bevel. Current from mercury arc rectifier used. Welding current, 115 volts, 60 amp. D. C. Length of weld, 10". Time required, 5 minutes.

No. 10—Section from two plates electric arc welded at right angles. ⅜" boiler plate. Edge of vertical plate beveled 30°. Welding current, 75 volts, 150 amp. D. C. Bare electrode.


6 A
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No. 297635

No. 11—¼" steel ring butt resistance weld. Riser at weld ground off. Welding current, 2 volts, 2,000 amp., 60 cycles. Time required, 3 minutes.

No. 12—⅜" steel ring butt resistance weld. Riser at weld ground off. Welding current, 2 volts, 3,000 amp., 60 cycles. Time required, 5 seconds.

No. 13—2" wrought iron pipe, ⅛" wall. Electric arc weld. Edges beveled 30°. Welding current, 75 volts, 65 amp. D. C. Time required, 6 minutes. Bare metal electrode, ⅛" diameter.

No. 14—Broken tap removed from work by welding on nut and backing out tap. Carbon electrode with metal filler used to make junction. Current, 75 volts, 40 amp. Time required, 1 minute.

No. 15—Butt welded copper rings. Thickness .031". Width ⅜". Outside dia. 2½". Resistance weld. Welding current, 2 volts, 25,000 amp., 60 cycles. Time, instantaneous. Flash weld.

No. 16—Spot weld. .047" steel to .025" brass. Welding current, 2 volts, approximately 5,000 amp., 60 cycles. Time, instantaneous for each spot. Flash spot weld. Strength, metal tears when pieces are pulled apart.

No. 17—Spot weld. .025" brass to .025" brass. Welding current 2 volts. Approximately 5,000 amp., 60 cycles. Time, instantaneous for each spot. Flash spot weld. Strength, metal tears when pieces are pulled apart.

No. 18—Spot weld. .063" A1 to .063" A1. Welding current, 2 volts, approximately 2,000 amp., 60 cycles. Time, approximately 4 seconds. Tungsten tips in welding electrodes.

No. 19—Line weld. .025" steel to .025" steel. Welding current, 9 volts, 2,000 amp. min., 5,000 amp. max., 60 cycles. Current, intermittent. 2,000 amp. on 75% and 5,000 amp. on 25% of time. Welding speed, 1" per second. Strength, metal tears when pieces are pulled apart.

No. 20—Spot weld. .025" copper to .025" copper. Welding current, 2 volts, approximately 2,000 amp., 60 cycles. Time, 3 seconds. Tungsten tips in welding electrode.

297643

SECTION B

CONTRIBUTION BY MESSRS. E. F. COLLINS AND P. A. MEYER, OF THE INDUSTRIAL HEATING DEPARTMENT OF THE SCHENECTADY WORKS.

Butt Welding of Copper: At the Motor Department of the Schenectady Plant of the General Electric Company, there are eleven butt welding machines in operation, welding the short-circuiting copper end rings to copper conductors, forming the squirrel cage induction motor rotors. Photographs Nos. 224131, 224133, 222668, 103702 and 233304 show views of several of these machines. (Pages 300-302.)

This process consists in clamping the two parts to be welded, to two massive jaws of a one turn secondary of a transformer, the current being applied to the primary through a solenoid operated switch after pressure is applied between the surfaces to be welded, by springs. The heavy secondary current at low voltage causes intense heating at the comparatively high resistance surface junction between the pieces to be welded, melting the copper.

As the copper at the point of weld reaches a molten condition, the spring pressure forces the two jaws together, squeezing out of the weld any oxide which may have formed, thus forming a complete homogeneous union of the element. The current is automatically cut off through the action of a switch, each movable jaw carries one of the contacts of the switch. The jaws are separated by the distance necessary to produce the squeezing action referred to above. The primary voltage of the transformer is varied by a voltage regulator for welding stock of different sizes.

No flux is used. A small stream of water is continually flowed on the weld creating an atmosphere of superheated steam, which not only prevents oxidation but also prohibits excessive superheating of the copper.

That the welding operation is successful is demonstrated by the fact that from records kept up to 1914, out of 15,500 rotors welded, only ten complaints had been received. Two of these were damaged by severe overload, not chargeable to the welders. This means a net of eight out of 15,500 rotors giving trouble, or slightly less than 1/20 of 1 per cent.

It should always be borne in mind that the success of any of these welding operations depends to a greater extent upon the workman than upon any other separate factor, and the excellent results the General Electric Company has obtained are due primarily to weeding out careless operators and encouraging and assisting those who are conscientious in their work. Photographs Nos. 226924, 25 and 26 (pages 302 and 303) are interesting in showing the efficiency of these welds in current capacity. The welders have capacities up to 80 KVA and weld copper of approximately 1¼" square maximum.

Photograph No. 237086 (page 304) shows a small butt welder of 15 KVA capacity in use in the Wire and Cable Department. Odd lengths and scraps of any size of brass and copper wire are welded together; in some cases to be insulated and used as good wire by filing off the burr formed at the weld; and in other cases to be cold drawn to the next size smaller wire.

Small Spot Welding and Line Welding: In the Punch Press Department of the Schenectady Plant of the General Electric Company, there are twenty motor-operated spot welders, of the designs shown in photographs No. 230790, 230791 and 232577. (Pages 304 and 305.) These are used for welding small spacers to the iron laminations of motors and generators for ventilating purposes, and hence are called "space block welders." These machines can weld 60 spots per minute when working continuously, not allowing for time to shift stock.

In three of the miscellaneous shops where some sheet metal work is done, foot-operated spot welders are used on numerous small jobs and even on regular production work at much less cost than riveting. Such machines are shown on photographs Nos. 235173, 235174 and 225638. (Pages 306 and 307.) It has, however, been found that in the oil switch department, a combination line and spot welder works to better advantage than an ordinary spot welder. Photographs Nos. 316125 (page 306) and 316126 (page 308) show a combination machine which has been in production for two years, spot and line welding switch boxes up to ⅛" thick. The machine will weld a continuous seam 6" long and the photograph shows a fixture adaptable for line butt welding the corner of a box. A separate removable fixture is used for spot welding, giving the machine an appearance similar to photograph No. 225638. (Page 306.)

Photographs Nos. 317949, 317950 and 317951 (pages 308 and 309) show a combination line and spot welder recently put into production having a capacity of 20 KVA and capable of spot and line welding material up to ¼" thickness and 18" long.

Photograph No. 317949 (page 308) shows a side view of

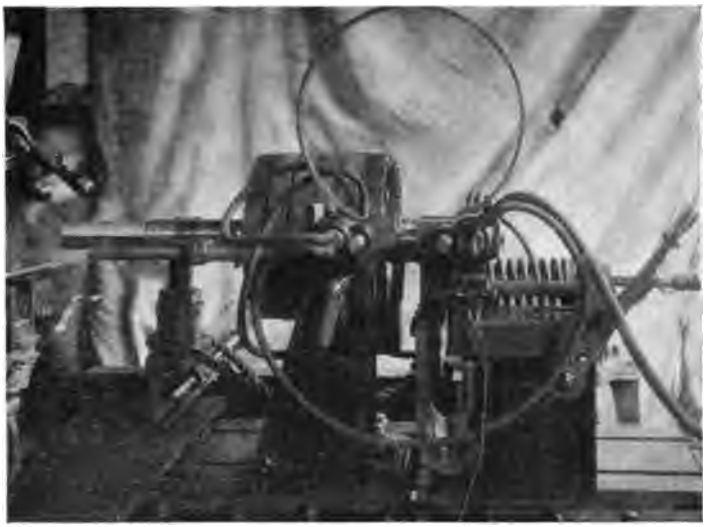
the line welding equipment, No. 317950 (page 309) a side view of the spot welding equipment, and No. 317951 an end view of both devices. The photographs show line welding fixtures for welding straight plates. These fixtures are removable, however, and fixtures may be substituted for welding corners of boxes or other similar straight lines.

Line welding machines, as developed at the Schenectady Works, comprise a transformer with a one turn secondary, through which a heavy current is delivered at low voltage to the material to be welded, through the medium of a stationary jaw and a rolling wheel. Both the stationary jaw and revolving wheel are motor-cooled and pressure is applied to the wheel the same as to the spot welding tip.

A small revolving switch mechanically geared to the driving motor and welding wheel operates a set of contactors or solenoid switches to throw on the power once a second, the power being on ⅜ of a second and off ⅝ of a second. The mechanism is so synchronized that during the ⅜ of a second the power is on, the welding wheel is rolling, and during the remaining ⅝ of a second the wheel is stationary under pressure while the molten metal is solidifying, thus completing the weld. Further tests are being carried out with a view of determining the maximum speed and greatest stroke for various thicknesses of stock. Line welding offers the best solution of the problems of making liquid tight tanks out of punched metal, and once adopted, offers limitless possibilities in the manufacture of "seamless" tubing.

224131. Large Electric Welding Machine

224133. Small Electric Welding Machine

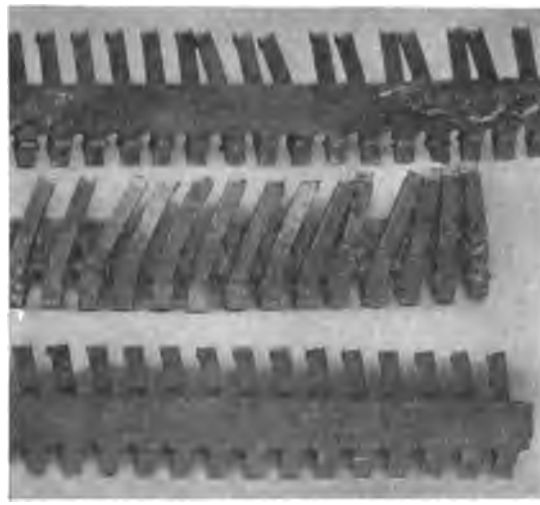


222668. Outfit for Electric Welding Induction Motor Rotors Rings and End Connections

103702. Copper Welding Outfit for Welding Copper Bars to Short Circuiting End Rings of Induction Motor Ends

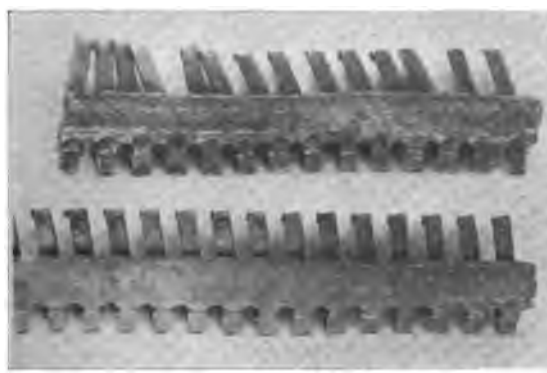
233304. Comparison of 1400 H.P. and 5 H.P. Form K Motors which are to have Electrically Welded End Rings

226924. Section of Welded Copper End Ring and Bars of 150 H.P. 750 R.P.M. Induction Motor Melted out by an Abnormal Condition.
"Note – that although End Rings and Bars became Molten none of the Welded Joints became Affected."



226925. Section of Welded Copper End Ring and Bars of 150 H.P. 750 R.P.M. Induction Motor Melted out by an Abnormal Condition.

"Note- that although the End Rings and Bars became Molten none of the Welded Joints were Affected."



226926. Section of Welded Copper End Ring and Bars of 150 H.P. 750 R.P.M, Induction Motor Melted out by an Abnormal Condition.

"Note -that although End Rings and Bars became Molten none of the Welded Joints were Affected."

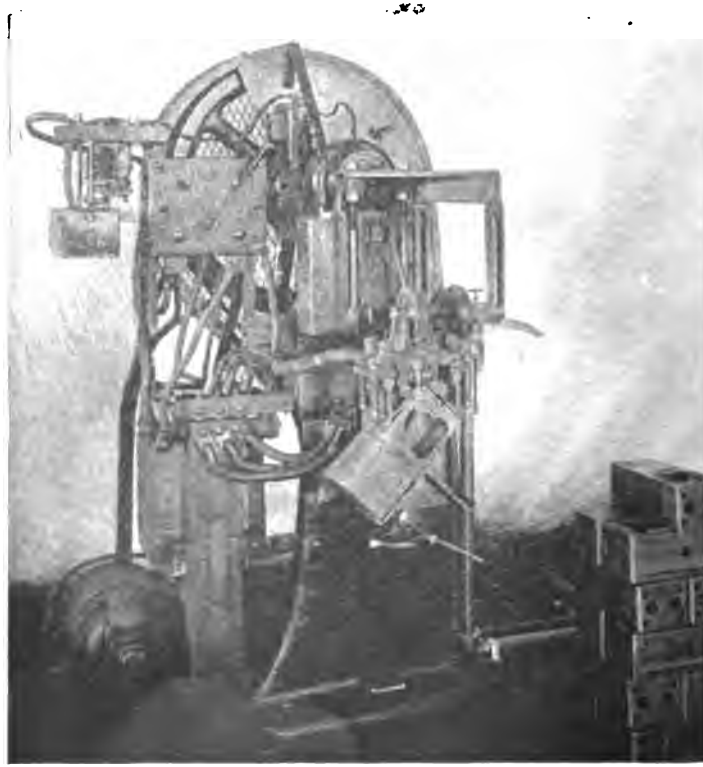
237086. 15 K.W.--550 V. Electric Butt Welder

232577. Space Block Electric Welding Department

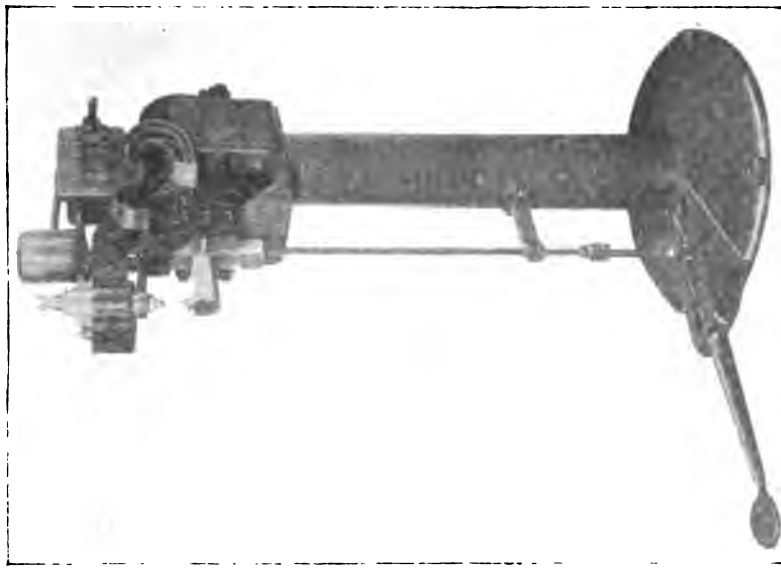
230790. Electric Space Block Welder

23791. Electric Space Block Welder

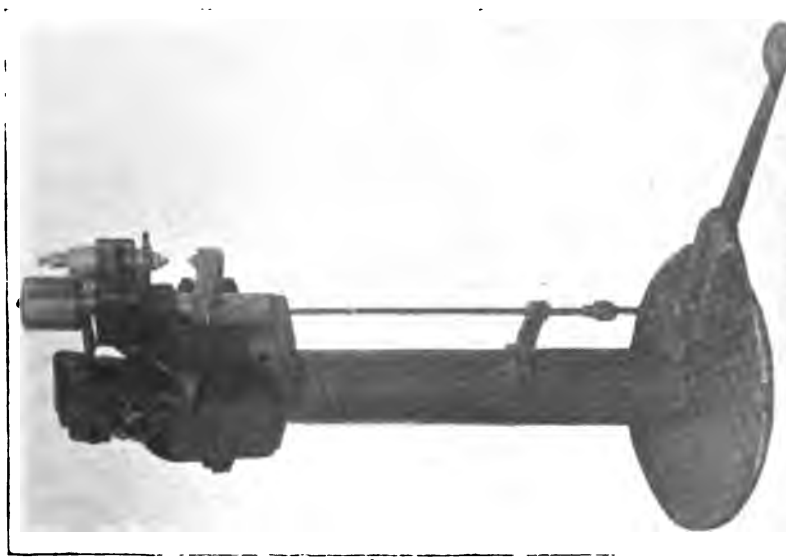
225638. Spot Welding Machine and its Products



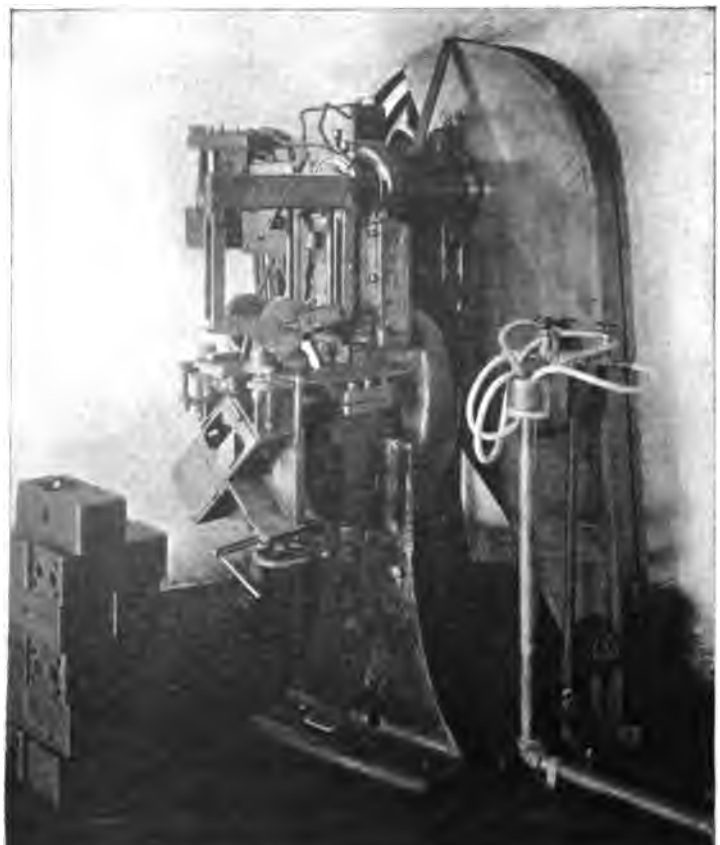
316125. Combination Electric Spot and Line Welding Machine



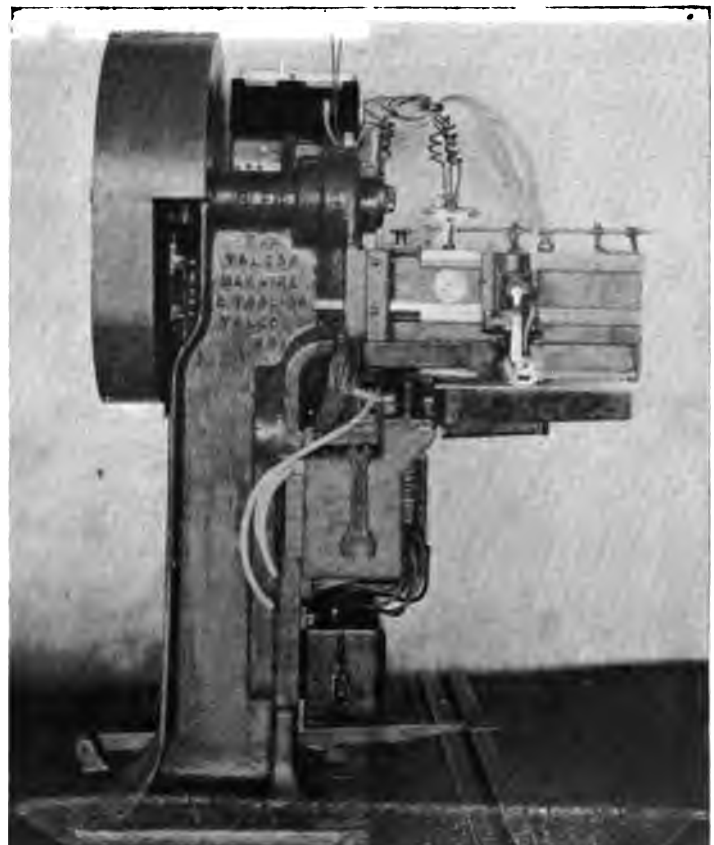
235174. Foot Operating Spot Welding Machine



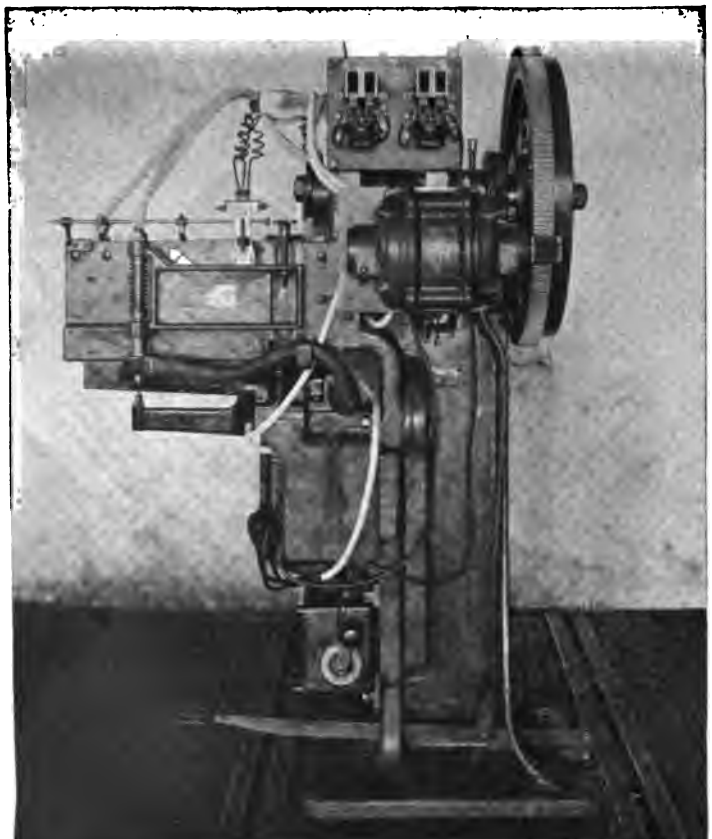
235173. Foot Operating Spot Welding Machine



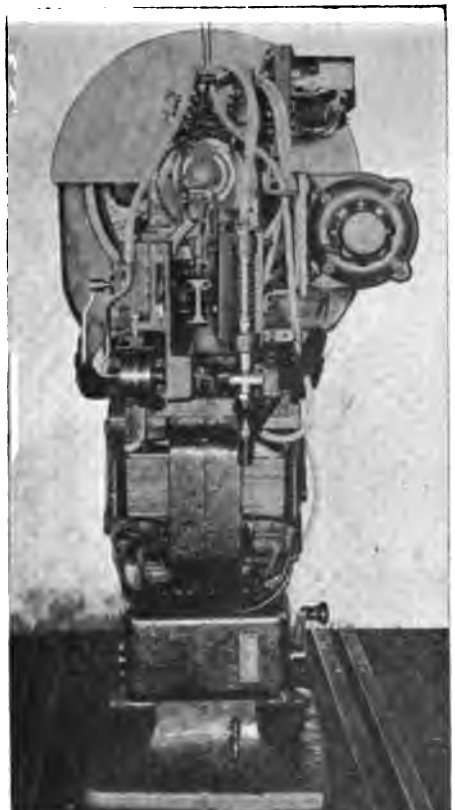
316126. Combination Electric Spot and Line Welding Machine



317949. Combination Spot and Line Welder Line Welder Side View



317950. Combination Spot and Line Welder No. 1—Spot Welded Side View



317951. Combination Spot and Line Welder No. 1—Spot Welder Side View

SECTION C

CONTRIBUTION BY MESSRS. J. A. CAPP AND G. H. WRIGHT, OF THE TESTING LABORATORY OF THE SCHENECTADY WORKS

INVESTIGATION OF ELECTRIC BUTT WELDING WITH PHOTOMICROGRAPHS

The object of this investigation was to determine the best practice in making butt-welds in the Thomson Electric Welding Machine so that the weld would be as little different from the parts welded as possible. The problem presented was the development of a method of welding whereby it would be possible to join the ends of a bar formed up into a ring in such a manner that the welded ring could be heat-treated and the metal in and about the weld would be as strong and ductile as the metal in the ring away from the weld.

The material selected for the experiments was a low carbon open-hearth steel, obtained under G. E. Specifications M-523, which require the steel to fall within the following specified limits in composition:

Carbon—Not less than 0.15% and not more than 0.25%;
Manganese—Not to exceed 0.50%;
Phosphorus—Not to exceed 0.04%;
Sulphur—Not to exceed 0.05%.

The steel was forged to approximately octagonal form, about one inch diameter between flats. The bars were then fully annealed by heating to 850 degrees Centigrade for four hours, followed by slow cooling. Pieces six inches long were used in the experiments. This length provided five inches for clamping and one inch to project beyond the clamp to meet the bar to which it was to be welded. The clamps of the machine were then set with two inches space between them when the bars to be welded were in contact.

The welding was done in a Thomson Electric Welder in which the clamps were pressed toward each other by a spring. The machine was a welder described as Catalog 80-A, of maximum capacity of 22,000 amperes.

The experiments were conducted by varying the current

used to make the weld and by holding the current for different lengths of time, and thereby producing welds with a greater or less amount of movement of the metal in and about the weld. The effects of the various changes in current and time were studied by examination of the accompanying changes in the microstructure of the steel.

The effect of varying the current was to vary the temperature of the metal surfaces in contact and this temperature ranged from about 1200 degrees Centigrade, which appeared to be the minimum temperature at which welding took place, up to practically the melting point of the steel. The effect of the varying time of application of the current was to confine the desired temperature closely to the surfaces to be welded, or to permit the high temperature to extend along the projecting ends of the rod from the contact surfaces toward the clamps. Changes in the condition of actual temperature and the extent to which the metal was heated to this temperature, permitted greater or less movement of the clamps while the weld was being made, and hence produced a greater or less swelling of the metal when welded. If the temperature was low and the heated length of the bars short, there was little or no movement, and hence little, if any, swelling of the diameter at the weld. If the temperature was high and the extent of heating great, not only was the swelling considerable, but there was actually a flash thrown out in the ring around the bars where welded. If the temperature was sufficiently high the throwing out of this flash was accompanied by a shower of sparks of molten metal.

After the welds were made a section of the welded bars, one-half inch long, was cut off, the weld being in the center of length of this section. The short section was then cut longitudinally in half. One of the test specimens thus obtained was examined without subsequent treatment; the other test specimen was annealed at 875 degrees Centigrade for about one hour, followed by slow cooling. The longitudinal surface taken from the center of the bar in each test specimen was polished and etched for examination under the microscope.

There were all told about thirty welds made, with varying temperature conditions as produced by variations in current and time. There are appended to the report twelve sheets of photomicrographs showing the results on six specimens. Three conditions of welding are illustrated in these six specimens:

1. The weld made with a high current applied for a relatively long period, which produces a high temperature existing over a considerable extent. The result was a weld with considerable degree of movement of the electrodes and the accompanying heavy flash around the bars at the weld.

2. A lower current applied for a shorter time, so as to produce a temperature lower than that in the first condition, yet of considerable extent. The result of this condition is a weld in which there is a considerable swelling of the metal at the weld and very little flash.
3. A current just sufficiently high to produce a welding temperature at the surfaces to be welded and applied for a time only sufficient to bring these surfaces to the desired temperature. The pressure applied then produces a weld with a very slight swell and with no flash.

The photomicrographs were taken:

1. At about four diameters to show a transverse section of half the diameter of the bar.
2. At a point in the heart of the welded area to show the typical structure resulting from welding under the conditions noted.
3. Outside the welded area, but close to the weld, showing the influence of the temperature in the vicinity of the weld upon the steel.
4. A longitudinal section through the weld after annealing.
5. The structure in the heart of the weld typical of the welded area after annealing.
6. The normal structure of the material away from the weld after annealing.

A study of the photomicrographs shows that the welds made under Condition 1 result in a considerable decarbonization of the steel in the immediate vicinity of the weld. The structure of the weld itself is irregular and ill-defined. In the immediate vicinity of the weld the steel shows evidence of overheating. Annealing, however, restores the structure close to the weld, but never can restore the normal structure in the weld because of the decarbonization. The weld under such conditions must be weaker than the balance of the steel.

In welds made under Condition 2, the effects of welding are similar to but less pronounced than those observed in welds made under Condition 1. There is less decarbonization and less ill-defined grain structure. Annealing brings the welded area nearly back in structure to the normal condition of the steel. Welds made under Condition 2, with little or no flash and with a great swell may be practically perfect, but there is liable to be unsoundness, due to the fact that there is actual melting of the steel at points where the surfaces are in contact. Such unsoundness is very marked in the case of welds made under Condition 1, being found, though with less degree in Condition 2.

In welds made under Condition 3 there is little or no structural disturbance of the steel so far as change of the proportion of structural constituents is concerned. In fact, after annealing it is difficult to say just where the actual weld was made. The photographs taken at low power show no unsoundness because the steel was never molten and gases were not produced. In the experiments made there was evidence shown that the results would have been better had the spring pressure available been higher. It was intended to continue the experiments with increased spring pressure, but necessity for using the machine in production prevented.

The conclusion to be drawn from the work is that welds may be made by the Thomson process in which the metal is structurally the same in the weld as in the areas away from the influences of the weld, that the conditions for such welding are:

That the surfaces in contact and the metal immediately in the vicinity of the weld be heated by the current to a temperature no higher than is customarily used in the smith shop for welding, i. e., 1200 to 1300 degrees Centigrade. This temperature must not be applied any longer than is necessary to bring the metal immediately behind the surface to be welded up to the welding heat. The less the length of bar heated for welding the better. The pressure applied during welding must be sufficient to force the metal into actual contact and slightly to deform it. At the temperature of welding the metal is plastic and the welding is accomplished by so pressing the plastic surfaces together that the grains of the metal are brought in such intimate contact that grain growth from one piece of metal to the other takes place. Welding made under these conditions is the duplicate of the welding made in the smith shop. The experiments have shown conclusively that welds made with conditions such that a heavy flash is thrown out about the weld are unreliable and of necessity weaker than the metal welded because of the structural change resulting from the decarbonization of the steel, and because of the blowholes formed when the metal is melted.

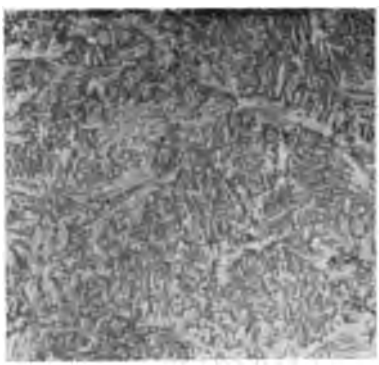
SAMPLE No. 3

Neg. A 17173

Longitudinal section thru weld as welded. Current 11,000, terminal voltage 6, light flash ⅛ in., spring pressure. Photo shows small blow-holes in specimen. 4 Diameters.

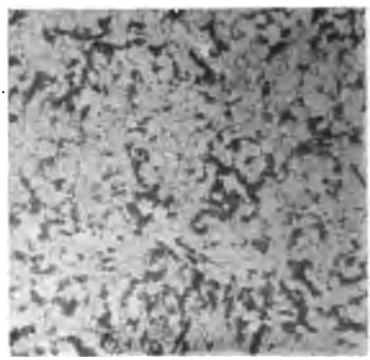
Neg. A 17174

Longitudinal section thru weld annealed from 875° C furnace cooled. Photo shows small blow-holes in specimen. 4 Diameters.



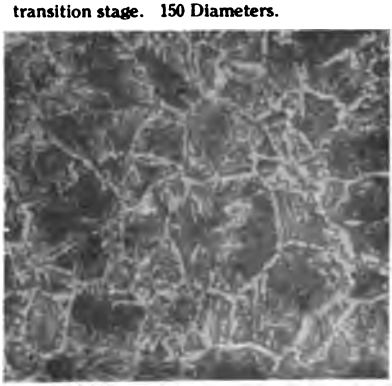
Neg. A 17185

Photo of weld shows mass of ferrite with numerous plates of carbide. Structure in transition stage. 150 Diameters.



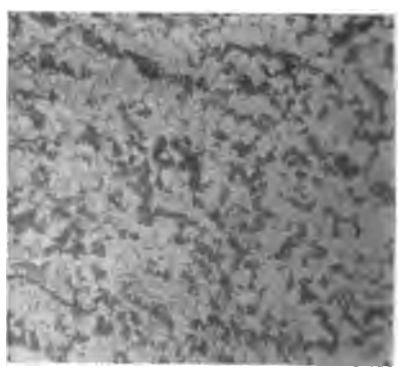
Neg. A 17197

Photo of weld shows ferrite grains with nearly normal pearlite areas. 150Diameters



Neg. A 17186

Photo close to weld shows sorbitic grains surrounded by irregular bands of ferrite. 150 Diameters.



Neg. A 17198

Photo close to weld showing ferrite grains with normal pearlite areas. 150 Diameters.

SAMPLE No. 6

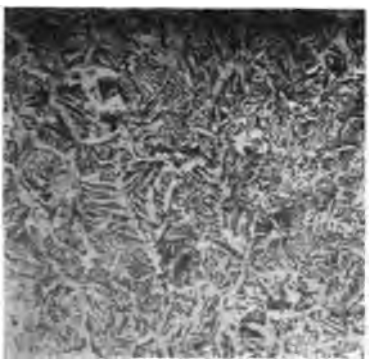
Neg. A 17165

Longitudinal section thru weld, as welded Terminal voltage 6; current 10,000; heavy flash ⅜ in.; spring pressure.

Photo shows large blow-hole in specimen. 4 Diameters.

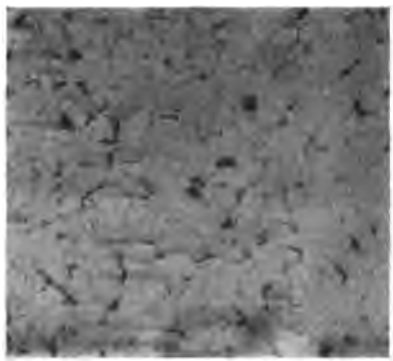
Neg. A 17166

Longitudinal section thru weld annealed from 875° C, furnace cooled. Photo shows blow-holes in specimen. 4 Diameters.



Neg. A 17177

Photo of weld shows ferrite mass with irregular bands of carbide. Structure in transition stage. 150 Diameters.

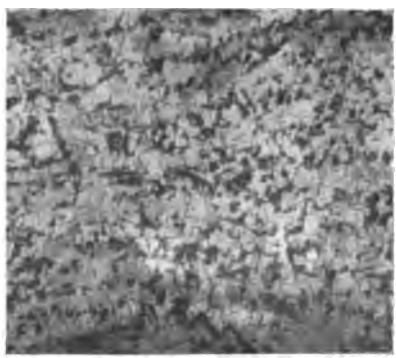


Neg. A 17189

Photo of weld shows ferrite grains with few dots of pearlite. Note absence of carbide. 150 Diameters.

Neg. A 17178

Photo close to weld shows large sorbitic grains surrounded with irregular bands of ferrite. 150 Diameters.



Neg. A 17190

Photo close to weld shows ferrite grain, studded with pearlite areas. Normal structure. 150 Diameters.

SAMPLE No. 10

Neg. A 17171

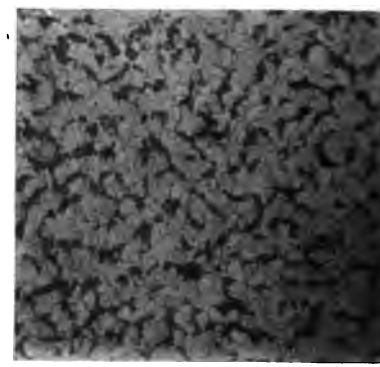
Longitudinal section thru weld annealed. Current 10,000; terminal voltage 6; light flash ⅛ in.; spring pressure. Photo shows large blow-hole in specimen. 4 Diameters.

Neg. A 17172

Longitudinal section thru weld annealed from 875° C furnace cooled. Photo shows small blow holes in specimen. 4 Diameters.

Neg. A. 17183

Photo of weld shows mass of ferrite with numerous plates of carbide. Structure in transition stage. 150 Diameters.

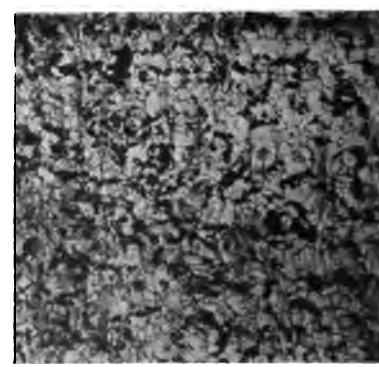


Neg. A 17195

Photo of weld shows mass of ferrite grains with nearly normal pearlite areas. 150 Diameters.

Neg. A 17184

Photo close to weld shows sorbitic grains with ferrite bands. Note effect of pressure on grains. 150 Diameters.



Neg. A 17196

Photo close to weld shows ferrite grains with normal pearlite areas. 150 Diameters.

SAMPLE No. 16

Neg. A 17163

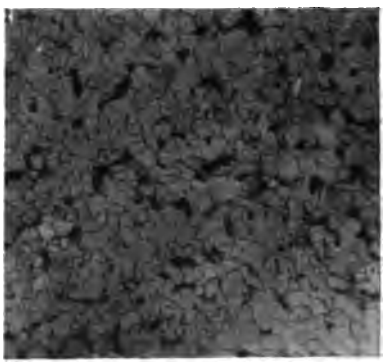
Longitudinal section thru weld as welded. Current 10,000; terminal voltage 6; heavy flash ⅜ in.; spring pressure. Photo shows large blow-holes in specimen. 4 Diameters.

Neg. A 17164

Longitudinal section thru weld annealed from 875 C, furnace cooled. Photo shows large blow-holes in specimen. 4 Diameters.

Neg. A 17175

Photo of weld shows mass of ferrite irregular in shape with few bands of carbide. 150 Diameters.

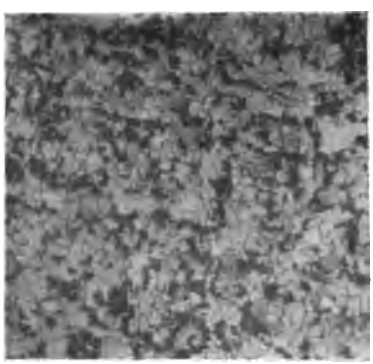


Neg. A 17187

Photo of weld showing ferrite grains with few areas of pearlite. Note absence of carbide. 150 Diameters.

Neg. A 17176

Photo close to weld shows sorbitic grains with ferrite boundaries. 150 Diameters.



Neg. A 17188

Photo close to weld showing ferrite grains studded with pearlite areas. Normal structure. 150 Diameters.

SAMPLE No. 22

Neg. A 17167

Longitudinal section thru weld as welded. Current 12,500; terminal voltage 6; no flash; spring pressure. Photo shows specimen free from blow-holes. 4 Diameters.

Neg. A 17168

Longitudinal section thru weld annealed at 875° C, furnace cooled. Photo shows specimen free from blow-holes. 4 Diameters.

Neg. A 17179

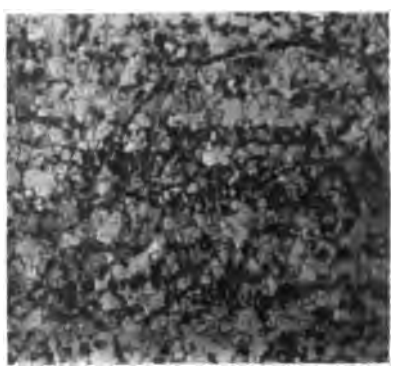
Photo of weld shows very large sorbitic grains with irregular band of ferrite. 150 Diameters.

Neg. A 17191

Photo of weld shows ferrite grains with normal pearlite areas. 150 Diameters.

Neg. A 17180

Photo close to weld shows sorbitic grains with ferrite bands. 150 Diameters.



Neg. A 17192

Photo close to weld shows ferrite grains with normal pearlite areas. 150 Diameters.

SAMPLE No. 28

Neg. A 17169
Longitudinal section thru weld as welded. Current 7,000; terminal voltage 6; no flash; spring pressure. Photo shows specimen free from blow-holes. 4 Diameters.

Neg. A 17170
Longitudinal section thru weld annealed from 875° C, furnace cooled. Photo shows specimen free from blow-holes.
4 Diameters.

Neg. A 17182
Photo close to weld. 150 Diameters.

Neg. A 17193
Photo of weld shows ferrite streak at junction of specimens. Pressure not sufficient for low current used. 150 Diameters.

Neg. A 17194
Photo close to weld shows ferrite grains with normal pearlite areas. 150 Diameters.

SECTION D: CONTRIBUTION BY MR. W. L. MERRILL, OF THE POWER AND MINING DEPARTMENT OF THE SCHENECTADY WORKS

ELECTRIC SPOT WELDING

Mr. Merrill has had charge of a great deal of very important work which has been done in connection with spot welding machinery for heavy plates and for carrying out tests of welds made with such machines. His remarks on this subject under date of April 4th, 1918, are as follows:

I take pleasure in submitting an outline of the work done at the Schenectady Plant of the General Electric Company in spot welding heavy plates.

In the latter part of the summer of 1917 it was decided to build a heavy spot welding machine to investigate the possibilities of welding plates from ¼" up. There was no data available on electrodes, pressures or currents for heavy plates and hence, a machine of very large capacity was designed. The limits of this machine in pressure and current was decided upon on the basis that should larger apparatus than this be required it would probably not be a feasible scheme. Therefore, a 2000 KV-A transformer was built, having capacity of 100,000 amperes at 20 volts. Hydraulic pressure arrangements were made to give pressure up to 36 tons at the electrodes. 500 KV-A and 6700 KV-A motor generator sets were assigned to this work.

The first part of our investigation consisted of determining the proper type of the electrode which would stand up under these heavy current densities and high pressures. Various complicate types of electrodes were built and tried. Our final choice, all things being considered, was the simplest type of all.

From the nature of the service it was apparent that the very high current densities at the point of contact of the electrode and the work necessitated some form of cooling. It was found by experimenting that if the section of the welding electrode was carried up any considerable distance from the work with the same section as the area of the electrode at the weld that it was impossible to water-cool the electrode sufficiently to give it any reasonable life.

Therefore, it was obvious that heavy masses of electrode material (copper) were necessary in the immediate vicinity of the point of contact, so that during the time of weld, the electrode, due to its great thermal capacity, would take up heat and keep the point of the electrode at a safe temperature. With this construction it was possible to have a very large cooling surface in the top of the electrode and the water passing through this at the time of the weld and between welds kept the points of the electrode cool enough for all practical purposes.

The life of the electrode under these conditions was considered sufficient, it being the intention to have several electrodes available at the machine and as the points became worn by dragging the plates through or blunted, due to usage, they would be removed from the machine and fresh ones supplied. The original electrodes would then be swedged back to form. Later experiments, however, demonstrated the practicability of using some thin copper cups, formed between dies, which would be very inexpensive, and clip over the point of the electrode proper; these to be renewed when worn.

During our first attempts at welding, we were much gratified to find that the limits in pressure, current and voltage which we had chosen were not only ample, but considerably in excess of any requirements which might be encountered, and, in justice to our engineers and factory, I wish to record that it was not necessary to change, improve or repair any part of the machine proper, the hydraulic equipment or the electrical equipment during the period of the tests which covered several months.

In anticipation of a very narrow zone of current, voltage and pressure to make successful welds, there were installed automatic recording current and voltage devices, and a special hydraulic recording device built which would plot the three curves automatically against seconds of time, because it was felt that with the three variables, current, pressure and time, any of which might necessarily be varied through a considerable range during the process of the weld, these devices would be necessary in order that when a successful weld had been made, it would be possible to reproduce it. The results of tests of our first welds, however, showed that there was a considerable range in pressure, current and time which would make successful welds. Having the conditions approximately correct to start with, there appeared to be no reason for changing these during the welding operation. Therefore, the automatic recording apparatus was abandoned.

Our method of procedure was, briefly, as follows:

Pieces of plate of various thicknesses, about 1-foot square, were welded together using different types of electrodes, different currents and different pressures. They were then taken

to the boiler shop and sheared through the middle of the weld, as shown in Photograph No. 109754 (page 327) (which, by the way, is no mean test of a weld). We then examined the different welds and checked them with the observed data of current and pressure and more welds were produced and the same sequence followed until the zone of time, current and pressure for a given thickness of plate was determined.

Samples 6" and 7" wide and 18" long, of various thicknesses, were welded together and pulled in the testing machine at the Rensselaer Polytechnic Institute, Troy, New York. These first samples, while showing the strength of the weld, were very good and about what we anticipated. The action of the machine, as will be seen from the photographs, was to bend the samples and rip them apart instead of shearing them; this, of course, due to the necessary offset in the testing machine to fit the sample.

A number of samples were then prepared with two rows of welds, differently arranged and spaced; also samples with butt strap. These showed good strength and in most cases were at 100% strength of joint in tension.

Double Spot Welding:

It will be noticed from inspection of the photographs of the machine that there was a single transformer with the positive and negative connected directly to the electrodes. This, of course, made a loop in the supply leads of the electrodes and naturally introduced considerable reactive drop which meant, first, lower power factor on the system; and, second, when plates of different widths were inserted, even though of the same thickness and the same type of weld desired, the primary voltage of the transformers would have to be adjusted for each width of plate, due to added induction in the circuit caused by the plate being inserted in the loop. It was, therefore, obvious that the machine would be more practicable were this feature eliminated, so that it would be possible to set the machine for a certain thickness of plate and reproduce the welds regardless of the width of the plates being welded. The connections to the transformer were then changed and all of the leads put on the same side of the plate being welded and two spots were welded at a time instead of one. Experience showed that this was a perfectly feasible method of welding and that the only point to which special attention would have to be given was some method of having equal pressure on each spot so that both welds would be made in the same length of time.

Our conclusions from this were that a successful machine for heavy plate welding with a deep throat should have two transformers, one on either side of the work with leads brought directly to the electrodes. The two secondary windings of

the transformers when the plate was inserted and the pressure applied would then be in series. This is the method adopted for the trial machines now under consideration. It is obvious that with a machine of this construction, in case only one weld is desired, or it is impossible to so locate the work that only one weld can be made, that a small dummy plate can be placed between the other electrodes.

PHOTOGRAPHS

Photo No. 109669—General arrangement of machine and transformer, hydraulic piping and special meter for plotting pressure curves during the weld.

Photo No. 109670—Shows the machine in operation welding 1" plate with two ½" butt straps.
The glass in the operator's hand is used to protect the eyes from flying particles of flux, which sometimes comes from the weld.

Photo No. 109747—Shows a 3" angle spot-welded to half-inch plate.
Two 12x18x½" thick plates welded, using buttons (thin steel discs), under the electrodes. Same type of plate using elongated electrode, making practically continuous weld.

Photo No. 109752—Shows some work done in this machine in welding various sizes of reinforcement together, used on concrete ship construction. It will be noted that sample pulled in the testing machine broke outside the weld.
This method has been proposed for welding up the reinforced structure of concrete ships. As far as I know, it has not been adopted by any one.
Time of making weld—two or three seconds.

Photo No. 109745—Other samples of same process.

Photo No. 109754—Shows (at the left), plate cut into by the shear for examination of the welds, as mentioned in the report. The small sample on the right of the photo shows a section of a ½" plate with approximately a ¾" weld. This sample pulled at 27000#, which was approximately the elastic limit of the specimen.

Photo No. 109749—Specimen No. 33 shows two ¾"x7" plates with the same thickness butt straps. Diameter of electrode, 1¾". This sample was made two welds at a time. The sample broke outside of the weld at 270,700 lbs. Lbs. per sq. in., 52,800.

Sample No. 17. ½"x6". Diameter of electrode, 1⅛". Sample broke outside weld at 172,600 lbs. Lbs. per sq. in., 57,500.

Weld showed no signs of failure.

Sample No. 23. ½"x6". 1⅛" spots. 184,300 lbs. Lbs. per sq. in., 61,400.

The unmarked sample was a duplicate of No. 17 and showed identical result except that plate did not break.

Photo No. 109748—Samples Nos. 14 and No. 16. ½"x7" plates. Three spots. One using buttons, other without buttons. This showed results of too low current.

Sample No. 16. Single spot. ½"x6". 2½" electrode. 106,400 lbs. Lbs. per sq. in. in plate 35,400. This is an example of how the welds tear out when one weld is made near the edge of the plate.

Sample No. 15 shows the same. Lower current was used, which was insufficient to make a proper weld. Weld sheared at 71,400. Stress in plate, 23,800.

Photo No. 109746—Side view of various samples, showing tearing action when a single row of spots is used and the testing machine is offset to accommodate this. It is, therefore, obvious from these tests that, the same as rivets, more than one row of spots should be used.

Conclusion:

Designs are under way for machines for trial, both for use as stationary tools in fabricating shops and portable machines to use on ships. Should these machines do successful work, a tremendous amount of preparatory work on the plates can be eliminated. While it may take longer to make a heavy spot weld than to drive a rivet in the shop by a bull riveter, yet the saving back of the bull riveter in the laying off, punching, reaming and bolting of the various parts will give a large overall gain in time, labor and cost.

109669. Machine for Experimental Welding for Heavy Steel by Electricity: Current Capacity 100,000 Amperes - Pressure Capacity 36 Tons.

109670. Machine for Experimental Welding of Heavy Steel by Electricity. Current Capacity 100,000 Amperes—Pressure Capacity 36 Tons Sample Weld Being Made.

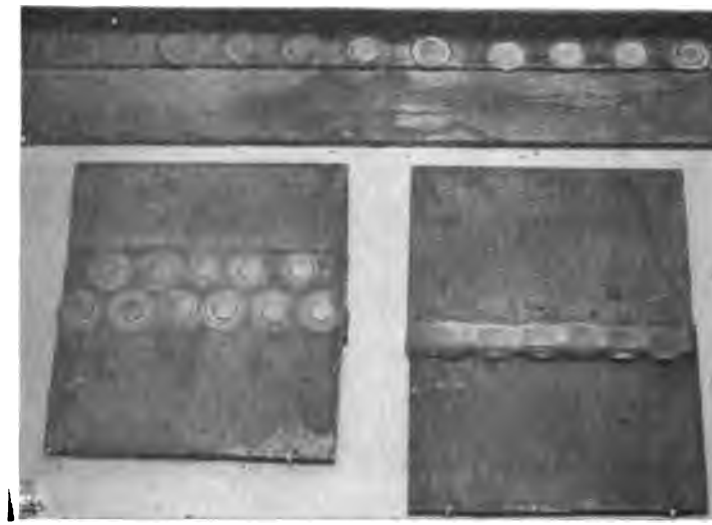


Photo — 109747

Photo -- 109752

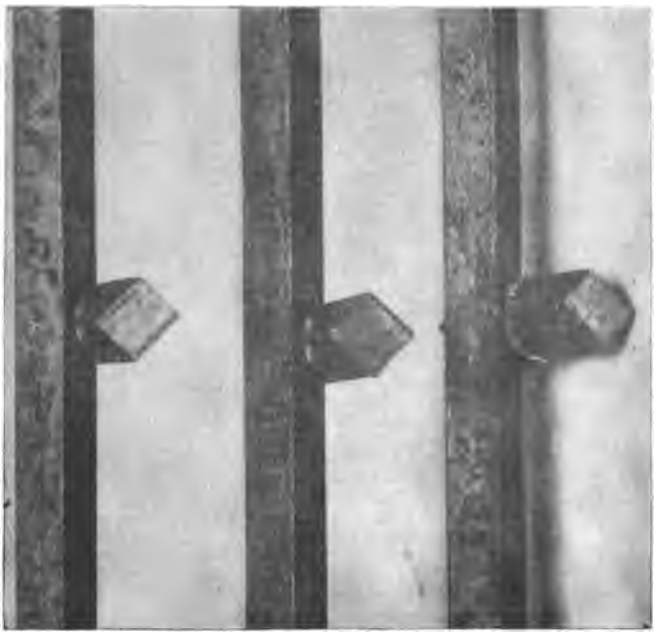


Photo — 109745

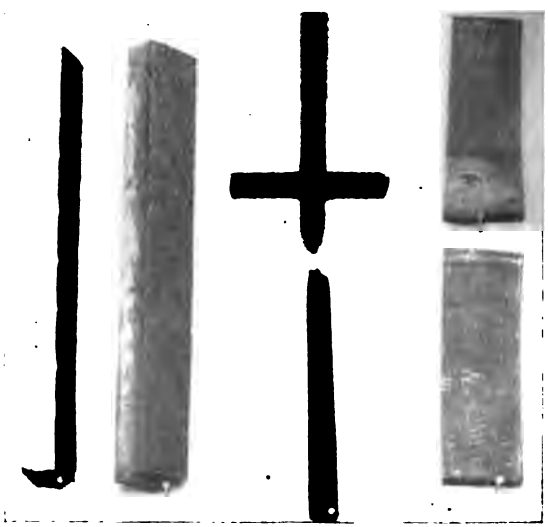


Photo — 109754

Photo — 109749

Photo — 109748

Photo — 109746

SECTION E: CONTRIBUTED BY MR. F. W. CALDWELL OF THE SCHENECTADY WORKS.

METHOD OF ELECTRIC WELDING IRON AND COPPER BY MEANS OF THE CARBON ARC PROCESS.

Mr. F. W. Caldwell describes this process in the following letter to me:

Schenectady, April 9, 1918.

Captain James Caldwell, R. E.
Dear Captain Caldwell:

With relation to the small sample of copper welded to steel by the electric arc, I would say that the welding of such metals may be done in a number of ways with the arc but principally I used the single carbon arc grounded to steel, getting a good puddle of hot steel, then dipping the copper gradually into the arc flame, the manipulation being practically the same as soldering with a gas torch. If the copper section is large and it is wanted to heat rapidly, simply ground the copper so that the arc will get directly to the copper as well as to the steel. The copper should not be allowed to become too hot as it will make a large flame, so large in fact sometimes as to cool the steel so that you get a cold shut instead of a weld. The process has been worked using an arc consisting of two carbons and almost any process which produces an arc which can be manipulated much like a gas torch should be satisfactory. There does not seem to be any reason why this process of manipulation cannot be applied to a great many combinations of metals.

The sectionalized weld between the head of a three-quarters inch cold rolled cap screw and a piece of thin copper tube three-sixteenths inch outside diameter which was handed to you was made with a 100-ampere carbon arc with the carbon on the positive side. The arc is allowed to play on the steel until a clear puddle about three-eighths inch in diameter is formed. Meanwhile the copper is slightly warmed in the gases of the arc. In the latter part of the operation, the arc is lengthened and the end of the copper inserted directly into the arc just long enough so the end begins to mushroom and possibly one or two drops of copper fall away without heating the copper too severely. Meanwhile the steel is kept melted and free of slag by the arc and then the two are simply pressed together.

The accompanying micrographs, Ruder A-134 and 133 show clearly the center band where the copper-steel alloy is formed between the copper and the steel.

One of the earlier experiments I made was ten or twelve years ago about the time when we were arc-welding seams on transformer tanks. At that time an arc-welded rail bond was made by welding a piece of copper rail bond cable to a piece of cold-rolled steel. I have shown the samples to Messrs Merrill and Hobart and they think that there should be a field for welding of this sort.

Yours very truly,
(Signed) F. W. CALDWELL.

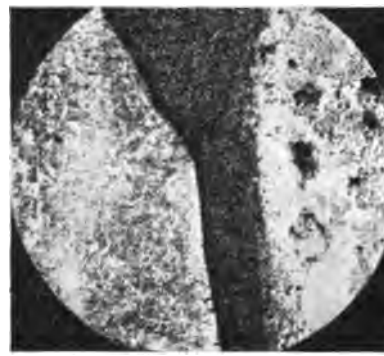
STEEL  COPPER

Photo Ruder A-133
Copper tube welded to head of cap screw with carbon arc showing band of copper steel alloy between steel and copper.

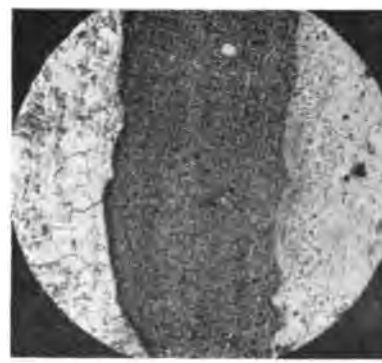
STEEL  COPPER

Photo Ruder A-134
Copper tube welded to head of cap screw with carbon arc showing band of copper steel alloy between steel and copper

SECTION F.

TESTS OF WELDING 1915.

COMPRISING:—
CARBON ARC SYSTEM.
BARE METAL ELECTRODE SYSTEM.
FLUX-COVERED METAL ELECTRODE.
OXYACETYLENE SYSTEM.

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REPORT ON G. E. ARC, QUASI ARC AND OXYACETYLENE WELDING.

The following tests were first started to obtain a direct comparison as to strength and cost between G. E. Arc Welding, using the metal electrode arc and also carbon electrode arc (with metal wire filler); and the Quasi method of welding. The Quasi is a process using metal electrodes covered with insulating or flux-producing material.

The tests were later extended to include a comparison of each of these methods with the oxyacetylene method.

G. E. ARC WELDING (Metal Electrodes).

Method.

In this method use is made of a bare steel wire. The arc is drawn between this wire and the work. The weld is made by filling in metal as it flows from the melting wire.

Direct Current.

Direct current at about 65 volts is generally used. Nearly all of the tests made by the G. E. Metal Electrode Method were made at 65 volts, and this voltage seems well adapted to general work.

A few tests were made at 105 volts D. C. The 105 volt-arc was more powerful and it was possible to weld 1" bar samples without a bevel (bevel is required for 65 volts) by burning off the corners. Welds made without bevel are quicker and cheaper to make but are not as strong (see table No. 8) as welds made with bevel at 65 volts.

Tests seem to indicate that welds on large work, requiring large metal electrodes and high current could be done quicker and to better advantage at higher voltages than 65 volts. This does not, necessarily, apply to work with the carbon arc.

Alternating Current.

Alternating current seems to have no advantages for welding, and many disadvantages compared to direct current. Frequencies of 40 and 60 cycles were tried.

Alternating Current (Bare Wire Electrodes).

With 65 volts it was practically impossible to weld with bare wire electrodes using alternating current. With 105

volts, the arc could, with difficulty, be established and a weld started. The difficulty of maintaining the arc prevented making any satisfactory welds.

Alternating Current (Coated Electrodes).

For Quasi welds see description of Quasi process, page 337.

It was found that almost any kind of covering on the wire would help hold the A. C. arc. The A. C. tests made were not very extensive, only a few coverings for the wire were tried. Practically the same results were obtained with the Quasi electrodes as with our coated electrodes on alternating current.

Welds can be made with **Alternating Current, using coated electrodes,** if no direct current is available, but the work **costs more** on account of the **extra expense** of the **electrodes** and the **welds are not** as **strong** and **uniform.**

Electrode.

The metal electrode used by the G. E. Company is mild steel wire, containing a very small per cent of carbon, also a small percentage of silicon, sulphur, phosphorus and manganese.

Very few tests were made with steel other than the above and there was not enough information obtained to determine, definitely, which is the best material for metal electrodes.

Polarity.

In the G. E. Method the positive side of the line is connected to the work to be welded, and the negative side to the wire electrode. The positive side of the arc is higher in temperature, and by connecting the negative side to the electrode it does not melt so fast, giving more time to heat the piece to be welded. It was also found that the electrode did not stick to the work as much when the polarity was reversed.

Range of Work.

The metal electrode arc method covers a wide range of work. These tests cover welds from $\frac{1}{16}$" sheet steel to 2" diameter bar. There is no difficulty in using this method in welding larger pieces up to as large sizes as it is desired to weld.

Large Pieces.

The few tests made show very good quality of welds on as large pieces as were welded. Making large welds is no different from small welds as to handling the arc and heating the metal. There occur shrinkage strains (as in any welding method when hot metal is filled in) which call for skill on the part of the welder in some cases.

These tests indicate that larger metal electrodes and higher currents might be used for large work with the result of increasing the welding speed and reducing costs.

The tests were not carried far enough to give information from which instructions could be given for welding with electrodes larger than shown in the following tables.

Welding Thin Sheet Steel.

In welding sheet steel as thin as 1/8" it is difficult to make a weld as smooth in appearance as by some other methods, but the welds are strong and are **cheaper** than by **any other method.**

It is possible to weld 1/16" sheet steel by using the proper size electrode and carefully regulating the current. The weld is difficult to make till the welder gets the necessary skill on account of the intense heat of the arc burning through. The welds on 1/16" sheet are rough in appearance but are strong and are cheaper than other methods.

It may be possible to weld sheet metal less than 1/16" by using very small electrodes and regulating the current to suit, and using extreme care in welding. Welding of very thin sheets by the arc method does not seem to be practical.

Limits.

So far as these tests show the **lower limit** for **ordinary** work in **arc** welding is about 1/16" or 3/32" thick sheet steel. There seems to be no limit to the increase in size of large pieces which can be handled.

The metal electrode arc is also well adapted to filling holes in steel castings and adding metal to steel surface (see page No. 9 for comparison with other methods).

G. E. ARC WELDING (Carbon Electrodes).

The same generator, voltage, panel, etc., used for metal electrode welding are equally useful for carbon arc welding.

Method.

In the G. E. Carbon Arc Method of welding the metal is melted by drawing an arc from the work to a carbon electrode, and metal is fed into the weld from a wire of the same material as used in the metal electrode welding. The heat of the arc melts this filler wire and the metal flows into the weld.

Range of Work.

The carbon arc is most useful in filling holes in steel castings in welding shafts and large parts.

The heat is too intense and hard to control to make it practical to weld sheet metal or small welds.

Welds made by the carbon arc are not as strong and the metal deposited is harder and more difficult to machine than in welds by other methods, yet it is possible to do very rapid **work** and the **quality** in class of work referred to above is usually **good enough** to meet **ordinary requirements.**

Report Number Seventeen

QUASI ARC WELDING.

Method.

The Quasi is a welding method using patented covered metal electrodes. 105 volts A. C. or D. C. is recommended by the Quasi Arc Weldtrode Company, who make these electrodes. The welding is done by drawing an arc between the electrode and the work as is done in all arc welding.

Electrode.

The metal electrode is a mild steel wire with a very small aluminum wire running along beside it. Around the two is wrapped asbestos thread making an insulation on the wire. The asbestos thread is held on by dipping the wire in something similar to water glass.

Welding (A. C.).

The use of the Quasi or of any coated or insulated electrode helps to hold the arc in A. C. welding, but even under the best conditions, A. C. welds will not compare with D. C. welds.

Welding (D. C.).

With the Quasi electrodes there is a tendency for slag from the insulated coating to get into the welds and form holes or weak spots. The use of the insulating covering on the wire is occasionally of use in getting into sharper bevels. This is more than offset by the increased cost of the electrode wire.

OXYACETYLENE WELDING

This process consisted in the use of oxygen and acetylene gases combined in a torch producing a very hot flame.

This method is in very successful use at the Schenectady Works in regular production on many lines of apparatus.

Comparison With Tests Made One Year Ago.

This method is highly developed, though improvements are continually being made as shown by comparison with a report of welds tested about one year ago. In the welding of thin sheet metal the results a year ago and those made in this set of tests both show very good welds, with high tensile strength. But in the 1″ and 2″ diameter samples the later welds show an increase of strength of 25% or more.

Range of Work.

The oxyacetylene process is best adapted to welding comparatively thin sheet metal.

Very good welding is done on $\frac{1}{32}$" or even thinner sheet steel.

With sheet steel of ¼" or larger the cost of gases becomes excessive.

On very thick pieces the heat from the flame spreads rapidly, and the waste of gas is so large that the method is not practical where any other method can be employed.

Metals Welded.

Not only steel but cast iron, brass and other metals can be welded with the oxyacetylene process.

TYPES OF WELDS.

Three sets of samples were made up and welded by each of the preceding welding methods. The samples selected were such as to represent a variety of welds, but were not great enough in number to cover all classes of welding. The greater part of the tests were made on thin sheet steel from $\frac{1}{16}$" to ¼".

Butt Welds.

Butt welds were made on samples of sheet steel from $\frac{1}{16}$" to ¼" in thickness and on 1" diameter bar, 2" diameter bar and on 1¼" steel plate. The 1" and 2" diameter bars were turned to size before making strength tests.

Right Angle Welds.

Welds of this type are such as would be made at the corner of a box in joining any two pieces at right angles.

These welds were made only from the outside of the box. The strength of such a weld could be increased by welding from both sides, but that would increase the cost, and the added strength is, in most cases, not needed.

Lap Welds.

Lapp welds represent a condition similar to a riveted joint. The pieces are overlapped and two welds are made, one at the end of each piece. This makes a very strong joint and should, if the welds are properly made, be as strong as the strength of the material.

Tank Welds.

These welds are used in welding in tank bottoms and similar work. These samples were welded only at one joint; that is, on the outside of the tank. If welded both outside and inside the strength of the weld would be greatly increased, but the added strength is not required in ordinary work.

Filling Drilled Holes.

Holes were drilled 2" in diameter and 2" deep in steel castings and steel bars. These were filled by the arc method only.

Adding Metal to Steel Surface.

Metal was added to finished steel blocks 3"x3"x13". Approximately ¼" of steel was added and then planed down ⅛". This was done by the arc method only.

Size of Test Pieces.

The size and shape of all the test pieces are given on K-1800972 and K-1800973. (Pages 352 and 353.)

Angle of Bevel.

No bevel is required on sheet metal welding up to and including ¼" in thickness. From ¼" to ½" the pieces are beveled from one side only and larger than ½" pieces are beveled from both sides.

A bevel of 90° for oxyacetylene welds was used in these tests, but satisfactory welds can be made at 60°, and the 60° bevel has been adapted as standard for oxyacetylene welds.

STRENGTH OF WELDS

The sheet samples in sizes from $\frac{1}{16}$" to ¼" had added metal at the weld, making the cross section larger than outside weld.

Lap and Butt Welds.

On these two types of welds where tensile strength only is required, the results as given in tables 5 and 6 show the strength of the weld nearly equal on the average to the strength of the material. If sufficient extra metal is added the strength of the weld may easily be made greater than the strength of the material.

Tank and Right Angle Welds.

These pieces were welded only on the outside of the tank or outside of the angle. On account of the direction of pull in testing such welds, the strain is a combination of shearing and tensile strain that break the weld at much less than the strength of the metal. The welds in these samples were all good welds, but the direction of strain gives a comparatively less per cent of strength as shown in tables 4 and 7.

Round Bars.

Bars of 1" and 2" diameter were beveled 90° for oxy-acetylene and G. E. Arc, and 45° for Quasi and G. E. Quasi.

Round bars were turned at the weld to the same size as the bar. The tests on round bars give results which show the true comparison of the strength of the weld compared to the strength of the bar.

STRENGTH TEST—ROUND BARS

(Turned to size)

	Pounds sq. in.	% Strength machine steel
Oxyacetylene	51250	93.2
G. E. Metal Electrode	51100	92.8
Quasi	43300	83.3
G. E.	40288	78.5

STRENGTH TEST

(Average all samples)

	Pounds sq. in.	% Strength machine steel
Oxyacetylene	42900	78.
G. E. Metal Electrode	42000	76.4
Quasi G. E. Quasi	41400	73.3

COST.

The following items of cost were figured at the prices given below. Welding costs are actual costs with nothing added for overhead expenses.

Electric Current, per Kw. Hr.	$.008
Oxygen, per 1000 ft.	2.200
Acetylene, per 1000 ft.	10.000
Steel wire (Electrodes) .25 Dia. per ft.	.005
Steel wire (Electrodes) .1875 Dia. per ft.	.003
Steel wire (Electrodes) .125 Dia. per ft.	.00157
Steel wire (Electrodes) .0937 Dia. per ft.	.0068
Steel wire (Electrodes) .0625 Dia. per ft.	.0004
No. 14 Quasi (Electrodes) .08 Dia. per ft.	.0459
No. 12 Quasi (Electrodes) .1035 Dia. per ft.	.0459
No. 10 Quasi (Electrodes) .1275 Dia. per ft.	.0568
No. 8 Quasi (Electrodes) .131 Dia. per ft.	.0787
No. 6 Quasi (Electrodes) .194 Dia. per ft.	.0913
No. 4 Quasi (Electrodes) .233 Dia. per ft.	.1147
Labor, per hr.	.30

COMPARISON OF COSTS.

G. E. Bare Wire	100%
G. E. Quasi	380%
Quasi	430%
Oxyacetylene	374%

For complete costs of welds on all tests by each method see tables 11, 12, 13, 14 and 15. (Pages 349 and 350.)

COMPARISON OF RESULTS.

G. E. Metal Electrode

This method is much cheaper than the Quasi, on account of the extra cost of covered electrode. It is cheaper and much faster than the oxyacetylene. It is not as fast as the carbon arc, but can be applied to many classes of work when the carbon arc cannot be used.

Comparison of G. E. and Quasi

The strength of welds is nearly the same. The slight difference shown in the tests in favor of the G. E. may be due to the conditions of test.

The bevel required is 90° for G. E., and 45° for Quasi, the Quasi requiring less bevel on account of the insulation on the wire.

In filling holes in cast and bar steel, the Quasi holes, when cut through, showed slag and blow-holes, while the G. E. were clean and in some cases the metal filled in could hardly be distinguished from the original metal. See photograph 107767. (Page 358.)

In adding metal to steel surface the sample made by the G. E. Metal Electrode, direct current, method showed a better surface, when machined, free from holes and more dense than the Quasi, alternating current or direct current samples.

ANALYSIS OF ELECTRODES.

	G. E. Metal	Quasi
Silicon	.10	.14
Sulphur	.061	.031
Phosphorus	.068	.024
Manganese	.50	.55
Carbon	.17 to .21	.17 to .21

COST OF G. E. AND QUASI

For an equal or slightly superior quality of work the cost of the G. E. method is only from one-third to one-quarter the Quasi cost (see tables).

Comparison of G. E. Metal Electrode and Oxyacetylene Methods.

The oxyacetylene makes a more smooth and uniform weld on metal as thin as $\frac{1}{16}$" or $\frac{1}{8}$", as the flame can be used to smooth down after the weld is made. With the arc the metal continues to flow from the metal electrode.

The arc has a tendency to burn through when welding $\frac{1}{16}$" or $\frac{3}{32}$" metal and requires more skill in handling on this class of work. But from $\frac{1}{8}$" up to any thickness the arc makes good welds, both in strength and appearance.

The tests show a difference in strength of approximately 3% in favor of the oxyacetylene process. The latter process has, however, been in regular use in shop production for some time, while the arc (except for filling holes) was used very little. The arc welds made at the beginning and at the end of these tests show that a great improvement in quality of work was made during the tests. If the instructions given on K-1800971 (page 351) (instruction sheet for Arc Welding) are followed, the results should give a uniformly good quality of welds.

The metal electrode arc has a great advantage over acetylene in rapid adding of metal to steel surfaces.

It is almost impossible to fill deep holes in cast steel with the oxyacetylene method while such work is rapidly done with the arc method. The metal electrode will add metal to surface or fill holes with clean soft metal easy to machine.

The arc weld has a tendency to be more brittle than the oxyacetylene, but by welding carefully and keeping within proper current limits this can, to some extent, be overcome.

The cost of the G. E. metal electrode welds from $\frac{1}{16}$" sheet steel up to $\frac{1}{4}$" and of welding bars of 1" diameter, is only about $\frac{1}{3}$ to $\frac{1}{4}$ the cost of the oxyacetylene. As the size of the pieces increase the costs show an increasing ratio in favor of the arc.

CARBON ARC.

The carbon arc with a steel wire filler is used, largely, for filling holes in steel castings. The heat is intense; the arc can be used to burn out a hole that is deep or difficult to get at. The metal can be filled in rapidly.

The quality of the work with the carbon arc is not as good as with the metal electrode. Carbon from the electrode is carried into the weld, making it hard to machine and of less tensile strength than the metal electrode weld.

The use of the carbon arc is limited, as it is not suitable for sheet steel welding. Much better results are secured by the metal electrode arc.

The cost of the carbon arc is slightly less than the metal electrode arc and very much less than any other method of welding.

Source of Power.

These tests were made at the Schenectady works of the General Electric Company. The direct current was obtained from an MP-6 pole, 80 Kw., 900 H. P. M., 60 volt generator, driven by a 250 volt D. C. motor.

A standard arc control panel CE-2613 was used. Diagram of connection L-1630069. (Not printed.)

The test with alternating current and 105 volts direct current was made in Building No. 11, the power being supplied by the Testing Department.

Blueprints 1800974-75-76-77 and 78 show method of preparing and welding joints with oxyacetylene. (Pages 353-355.)

NOTE—These tests are being continued, and this report may be revised or a later report may be made.

No. 1—TABLE FOR G. E. ARC WELDING

Size Stock	Kind Weld	Time Min.	Angle	Distance Apart of Points	Size Wire	Length Wire In	Amperes Start	Amperes Finish
1/16x1½	Butt	1	none	3/32	1/16	6	42	30
"	R. Ang.	⅔	"	3/32	1/16	4	42	30
1½x1/18	Butt	2	"	1/16	3/32	8	90	75
"	Lap	4	"	—	3/32	18	85	75
"	90°	2½	"	1/16	3/32	12	90	70
"	Tank	3½	"	—	3/32	15	85	70
1½x ¼	Butt	2	"	⅛	⅛	14	120	115
"	Lap	7	"	—	⅛	26	120	110
"	90°	2	"	3/32	⅛	18	110	100
"	Tank	3	"	—	⅛	18	115	110
4½x1½	Butt	62	45°	⅛	3/16	190	150	130
1" Dia.	Butt	10½	45°	1/16	3/16	26	145	130
2" Dia.	Butt	49	45°	3/32	3/16	150	150	130
Hole 2" Dia. 2" Deep	—	40	—	—	¼	150	230	175
6' x¼"	Butt	80	none	3/16	1/18	316	120	90
Add ¼ stock to 3x3x12"	—	97	—	—	3/16	295	130	115
Hole 2" Dia. 20" Deep Carbon Arc	—	—	—	—	¼	—	290	270

No. 2—TABLE FOR QUASI WELDING

Size Stock	Kind Weld	Time Min.	Angle	Distance Apart of Points	Size Wire	Length Wire In	Amperes Start	Amperes Finish
1¼x ⅛	Butt	3	none	1/16	#10	5	50	45
"	Lap	3⅓	"	—	#10	9	50	45
"	90°	1	"	1/16	#10	5	50	50
"	Tank	1¼	"	—	#10	5	45	45
1½x ¼	Butt	3½	"	3/32	#10	14	80	70
"	Lap	10½	"	—	#10	26	70	60
"	90°	2½	"	3/32	#10	9	90	70
"	Tank	1⅔	"	—	#10	8	100	70
1" Dia.	Butt	8½	22½°	3/32	#10	42	120	110
2" Dia.	Butt	22	22½°	3/32	# 8	108	190	150
6' x¼"	Butt	50	none	1/16	#10	290	100	80
Hole 2" Dia. 2" deep		45		—	# 4	180	220	180
1¼x4½	Butt	20	22½°	3/32	# 8	108	200	160

No. 4—STRENGTH TEST—WELDED SAMPLES.

Mark	Size	Kind of Weld		Ultimate Strength	Strength Per Sq. In.	Per Cent.	Av. Per Cent.	Break In
2-219	1½x ¼"	Rt. Ang.	GE	10595	27600	50.		Thru weld
2-221	"	"	GE	15665	41800	76.	61.	"
2-220	"	"	GE	11765	31300	57.		"
2-117	"	"	Q	12456	34100	62.	59.2	"
2-118	"	"	Q	11610	31000	56.4		"
2-319	"	"	GEQ	9000	24000	43.7	43.7	"
2-218	1½x⅛"	"	GE	6410	34200	62.		"
2-217	"	"	GE	8295	43000	76.	74.3	"
2-216	"	"	GE	8610	46800	83.		"
2-120	"	"	Q	8405	26800	52.4		"
2-121	"	"	Q	4850	25800	47.	66.4	"
2-119	"	"	Q	16646	88500	100.		"
2-316	"	"	GEQ	7906	45100	76.5	76.5	"

NOTE: Samples marked from 100 to 199 were made by Quasi Arc at 105 volts.
Samples marked from 200 to 299 were made with G. E. bare wire at 65 volts.
Samples marked from 300 to 399 were made with Quasi Arc at 65 volts.

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No. 3—STRENGTH TEST—WELDED SAMPLES.

Mark	Size	Kind of Weld	Ultimate Strength	Strength Per Sp. In.	Per Cent.	Av. Per Cent.	Break In
GE-13	1"x1"	Butt	46830	48830	88.7		Weld
"	"	"	35565	35565	64.5	79.2	"
"	"	"	46400	46400	84.5		"
Q-13	"	"	52225	52225	94.6		"
"	"	"	57485	57485	104.	90.	"
"	"	"	39900	39900	72.5		"
GEQ-13	"	"	46830	46830	85.	75.	"
"	"	"	35780	35780	65.		"
1-208	2" Dia.	"	160130	51000	92.5		"
1-209	"	" G. E.	150385	47700	87.	93.8	"
1-211	"	"	176060	56000	102.		"
Carbon	"	"	108380	34400	62.5	62.5	"
1-110	"	"	140320	44800	81.5		"
1-111	"	" Q	128120	40300	73.4	80.6	"
1-112	"	"	150500	48000	87.		"
1-312	"	" GEQ	134125	42800	78.	78.	"
1-214	1" Dia.	"	43075	54900	99.7		"
1-213	"	" GE	36705	46600	84.5	91.9	"
1-212	"	"	39935	50400	91.5		"
1-113	"	"	37135	47300	86.		"
1-114	"	" Q	39745	50500	92.	86.	"
1-115	"	"	34705	44000	80.		"
1-314	"	" GEQ	32345	41100	74.5	79.	"
1-313	"	"	36375	46000	83.5		"

NOTE: Samples marked from 100 to 199 were made by Quasi Arc at 105 volts.
Samples marked from 200 to 299 were made with G. E. bare wire at 65 volts.
Samples marked from 300 to 399 were made with Quasi Arc at 65 volts.

8-25-15

No. 5—STRENGTH TEST—WELDED SAMPLES.

Mark	Size	Kind of Weld		Ultimate Strength	Strength Per Sq. In.	Per Cent.	Av. Per Cent.	Break In
3-222	1½x¼"	Butt		20245	53800	98.		Thru weld
3-224	"	"	GE	20330	54500	99.	94.1	"
3-225	"	"		17645	47000	85.5		"
3-122	"	"		21675	58000	100.		"
3-123	"	"	Q	20810	53500	97.5	99.1	"
3-124	"	"		21125	56500	100.		"
3-325	"	"	GEQ	19370	51400	93.4	93.4	"
3-225	1½x⅛"	"		10830	58600	100.		in bar
3-227	"	"	GE	10365	55000	100.	95.8	"
3-226	"	"		9055	48200	87.5		"
3-125	"	"		13720	73000	100.		Thru weld
3-126	"	"	Q	12910	68800	100.	100.	"
3-127	"	"		10765	57200	100.		"
3-322	"	"	GEQ	9895	52500	95.5	95.5	in bar

NOTE: Samples marked from 100 to 199 were made by Quasi Arc at 105 volts.
Samples marked from 200 to 299 were made with G. E. bare wire at 65 volts.
Samples marked from 300 to 399 were made with Quasi Arc at 65 volts.
Samples marked from 300 to 399 were made with Quasi Arc at 65 volts.

8-25-15

No. 6—STRENGTH TEST—WELDED SAMPLES.

Mark	Size	Kind of Weld		Ultimate Strength	Strength Per Sq. In.	Per Cent.	Av. Per Cent.	Break In
4-228	1½x¼"	Lap		14320	38200	69.5		Thru weld
4-229	"	"	GE	19895	53000	95.5	88.6	"
4-230	"	"		22565	60000	100.		"
4-130	"	"		22985	61200	100.		in bar
4-129	"	"	Q	21405	57400	100.	100.	"
4-128	"	"		24070	6440	100.		"
4-331	"	"	GEQ	24330	64500	100.	100.	Thru weld
4-261	1½x⅛"	"		8640	46000	83.5		in bar
4-231	"	"	GE	9965	53000	96.5	93.3	"
4-233	"	"		13545	72100	100.		"
4-131	"	"		8820	47000	85.5		"
4-132	"	"	Q	8890	47800	85.7	90.4	"
4-133	"	"		13815	73700	100.		"
4-328	"	"	GEQ	9100	54500	99.	99.	"

NOTE: Samples marked from 100 to 199 were made by Quasi Arc at 105 volts.
Samples marked from 200 to 299 were made with G. E. bare wire at 65 volts.
Samples marked 300 to 399 were made with Quasi Arc at 65 volts.

8-25-15

No. 7—STRENGTH TEST—WELDED SAMPLES

Mark	Size	Kind of Weld		Ultimate Strength	Strength Per Sq. In.	Per Cent.	Av. Per Cent.	Break In
5-234	1½x¼"	Tank		7120	19950	34.5		Thru weld
5-235	"	"	GE	6465	17100	31.0	32.6	"
5-236	"	"		6715	17860	32.5		"
5-134	"	"		6900	18590	33.4		"
5-135	"	"	Q	5470	14550	26.5	29.7	"
5-136	"	"		6070	16180	29.4		"
5-337	"	"	GEQ	6975	18500	33.6	33.6	"
5-237	1½x⅛"	"		2690	14360	26.0		"
5-238	"	"	GE	3025	16200	29.4	27.1	"
5-239	"	"		2670	14240	25.9		"
5-137	"	"		3250	17320	31.5		"
5-138	"	"	Q	2770	14700	26.8	29.6	"
5-139	"	"		3270	17430	31.7		"
5-334	"	"	GEQ	2405	12620	23.3	23.3	"

NOTE: Samples marked from 100 to 199 were made by Quasi Arc at 105 volts.
Samples marked from 200 to 299 were made with G. E. bare wire at 65 volts.
Samples marked from 300 to 399 were made with Quasi Arc at 65 volts.

8-25-15

No. 8—STRENGTH TEST—WELDED SAMPLES.

Mark	Size	Kind of Weld	Ultimate Strength	Strength Per Sq. In.	Per Cent.	Av. Per Cent.	Break In
410	2" Dia.	Butt	111150	35400	63.5	63.5	Thru weld
413	1" Dia.	"	28450	48000	88.	88.	"
414	" "	"	25350	38000	69.		"
415	" "	"	26800	41000	74.5	71.7	"

NOTE: Above samples made with bare wire at 105 volts. 414 and 415 were made without bevel.

No. 9—STRENGTH TEST OF WELDED SAMPLES MADE BY OXY-ACETYLENE

Mark	Size	Kind of Weld	Ultimate Strength	Strength Per Sq. In.	Per Cent.	Av. Per Cent.	Break In
1	1″ Sq.	Butt	50600	50600	92.		Weld
2	"	"	50235	50235	91.	91.	"
3	"	"	49795	49795	90.		"
1-514	1″ Dia.	"	43315	55000	100.		"
1-515	"	"	44885	56900	100.	100.	"
1-513	"	"	45160	57400	100.		"
1-511	2″ Dia.	"	15520	47500	86.5		"
1-512	"	"	149515	46800	85.2	86.4	"
1-510	"	"	153900	48200	87.5		"
2-516	⅛x1½″	R. Ang.	7515	40000	73.		Bar
2-517	"	"	7645	40500	73.5	74.2	"
2-518	"	"	7915	42000	76.3		"
2-519	¼x1½″	"	12605	33600	59.2		Weld
2-520	"	"	12820	34000	61.5	59.9	"
2-521	"	"	12150	32300	59.0		"
3-525	⅛x1½″	Butt	10890	58000	100.		Bar
3-526	"	"	10775	57500	100.	100.	Weld
3-527	"	"	10935	68500	100.		Bar
3-522	¼x1½″	"	21460	57000	100.		Bar
3-523	"	"	22025	58600	100.	98.8	Bar
3 524	"	"	20785	53300	96.5		Weld

No. 10—STRENGTH TEST OF WELDED SAMPLES MADE BY OXY-ACETYLENE

Mark	Size	Kind of Weld	Ultimate Strength	Strength Per Sq. In.	Per Cent.	Av. Per Cent.	Break In
4-528	⅛x1½″	Lap	10970	58500	100.		Bar
4-529	"	"	10725	57500	100.	100.	Bar
4-530	"	"	10965	68600	100.		Bar
4-531	¼x1½″	"	21905	59300	100.		Bar
4-532	"	"	22085	58700	100.	100.	Bar
4-533	"	"	21435	57000	100.		Bar
5-537	⅛x1½″	Tank	2495	13300	24.6		Bar
5-538	"	"	2210	11750	21.4	22.6	Bar
5-539	"	"	2760	12106	22.		Weld
5-534	¼x1½″	"	4936	13100	23.8		Weld
5-535	"	"	5675	15100	27.4	26.3	Bar
5-536	"	"	5196	15600	24.7		Weld

No. 11—WELDING COSTS
LABOR COST.

Size	Weld	G. E.	G. E. Q.	Quasi	Acetylene
1/8x1½"	Rt. Ang.	.0033	.....	.....	.0094
"	Butt	.005	.....	.....	.009
⅛x1½"	Butt	.01	.015	.015	.019
"	Rt. Ang.	.001	.005	.014	.0125
"	Tank	.016	.006	.004	.036
"	Lap	.02	.018	.012	.051
¼x1½"	Butt	.01	.016	.02	.0304
"	Rt. Ang.	.01	.013	.0175	.0304
"	Tank	.013	.007	.009	.048
"	Lap	.035	.051	.02	.033
1" Dia.	Butt	.052	.042	.046	.113
2" Dia.	Butt	.245	.11	.185	.422
1¼x4½"	Butt	.31	.10	.114	56.5
Hole 2" Dia. 2" Deep		.20	.225	.....	.....

No. 12—WELDING COSTS.
ELECTRODE COST.

Size	Weld	G. E.	G. E. Q.	Quasi	Acetylene Wire Filler
1/8x1½"	Rt. Ang.	.00026	.....	.....	.00006
"	Butt	.00026	.....	.....	.00006
⅛x1½"	Butt	.0005	.023	.0688	.0003
"	Rt. Ang.	.0008	.023	.0343	.0004
"	Tank	.001	.023	.007	.0003
"	Lap	.0012	.042	.05	.0006
¼x1½"	Butt	.0018	.066	.0845	.0009
"	Rt. Ang.	.0023	.042	.0625	.001
"	Tank	.0023	.037	.0282	.001
"	Lap	.0031	.122	.152	.0015
1" Dia.	Butt	.007	.197	.319	.004
2" Dia.	Butt	.037	.708	.859	.03
1¼x4½"	Butt	.047	.70	1.13	.032
Hole 2" Dia. 2" Deep		.068	1.72	.....	.....

No. 13—KILOWATT AND GAS COST

Size	Weld	G. E.	G. E. Q.	Quasi	Oxy.	Acet.	Total Oxygen and Acetylene
1/8x1½"	Rt. Ang.	.00022	.....	.....	.0036	.0015	.0051
"	Butt	.00022	.....	.....	.0035	.0014	.0049
⅛x1½"	Butt	.0006	.0005	.0019	.003	.0078	.0108
"	Rt. Ang.	.0009	.0004	.0015	.00206	.0053	.0073
"	Tank	.0009	.0005	.0006	.0037	.0111	.0148
"	Lap	.0012	.0009	.002	.0078	.0222	.03
¼x1½"	Butt	.0013	.0013	.0032	.0121	.0161	.0282
"	Rt. Ang.	.0017	.0012	.0023	.0113	.015	.0263
"	Tank	.002	.001	.0012	.0212	.0228	.044
"	Lap	.0025	.0023	.0042	.041	.042	.083
1" Dia.	Butt	.007	.003	.0083	.0525	.091	.1435
2" Dia.	Butt	.03	.017	.025	.381	.779	1.160
1¼x4½"	Butt	.043	.0175	.041	.52	1.05	1.57
Hole 2" Dia. 2" Deep		.03	.04	.....	.....	.....	.....

No. 14—TOTAL COST

Size	Weld	G. E.	G. E. Q.	Quasi	Acetylene
"	Butt	.0055	.....	.....	.014
⅛x1½"	Butt	.011	.0385	.085	.03
"	Rt. Ang.	.013	.0284	.05	.02
"	Tank	.0179	.0295	.011	.05
"	Lap	.0224	.0614	.064	.081
¼x1½"	Butt	.013	.083	.107	.059
"	Rt. Ang.	.014	.056	.082	.057
"	Tank	.019	.045	.039	.093
"	Lap	.04	.175	.176	.168
1" Dia.	Butt	.066	.24	.37	.262
2" Dia.	Butt	.31	.83	1.07	1.612
1¼x4½"	Butt	.46	.82	1.28	2.16
Hole 2" Dia. 2" Deep		.298	1.98	.....	.....

No. 15—PERCENTAGE COST OF DIFFERENT METHODS OF WELDING COMPARED WITH THE G. E. METHOD TAKEN AS 100%

Size	Weld	G. E.	G. E. Q.	Quasi	Acet.
⅛x1½"	Rt. Ang.	100%	.....	.....	362%
⅛x1½"	Butt	"	350%	770%	278%
"	Rt. Ang.	"	218%	388%	154%
"	Tank	"	165%	61.5%	279%
"	Lap	"	274%	290%	362%
¼x1½"	Butt	"	637%	820%	455%
"	Rt. Ang.	"	400%	585%	407%
"	Tank	"	237%	205%	486%
"	Lap	"	438%	410%	420%
1" Dia.	Butt	"	364%	560%	397%
2" Dia.	Butt	"	267%	345%	520%
1¼x4½"	Butt	"	178%	278%	470%
Hole 2" Dia. 2" Deep		"	670%	.....	.....
AVERAGE		100%	380%	480%	374%

INSTRUCTION SHEET FOR ARC WELDING

METAL ELECTRODE WELDING TABLE

STEEL			METAL ELECTRODE	DIRECT CURRENT		BUTT WELDS			AT ANGLE WELDS			TANK WELDS			LAP WELDS		
SHEET	SQUARE	ROUND				FIGURE	BEVEL	ROOT APART A	FIGURE	BEVEL	ROOT APART B	FIGURE	BEVEL	C	FIGURE	BEVEL	D
THICKNESS	SIZE	DIAM.	SIZE	MAX	MIN												
1/16"			1/16"	40	30	1	0°	1/32"	4	NONE	1/32"	5	NONE	1/16"	6	NONE	1/2"
3/32"			3/32"	90	70	1	0°		4	NONE		5	NONE	3/32"	6	NONE	1/2"
1/8"	1/8"	1/8"	3/32"	90	70	1	0°	3/32"	4	NONE	3/32"	5	NONE	1/8"	6	NONE	1/2"
3/16"	3/16"	3/16"	1/8"	120	100	1	0°	1/8"	4	NONE	3/32"	5	NONE	3/16"	6	NONE	1/2"
1/4"	1/4"	1/4"	1/8"	120	100	1	0°	1/8"	4	NONE	3/32"	5	NONE	1/4"	6	NONE	1/2"
1/4"			3/16"	150	115	1	0°	3/16"	4	NONE	3/32"	5	NONE	1/4"	6	NONE	1/2"
5/16"			3/16"	150	115	2	45°	3/32"	4	NONE	3/32"	5	NONE	5/16"	6	NONE	3/4"
3/8"			3/16"	150	115	2	45°	3/32"	4	NONE	3/32"	5	NONE	3/16"	6	NONE	3/4"
7/16"			3/16"	150	115	2	45°	3/32"	4	NONE	3/32"	5	NONE	7/16"	6	NONE	3/4"
1/2"			3/16"	150	115	2	45°	3/32"	4	NONE	3/32"	5	NONE	1/2"	6	NONE	1"
		2"	3/16"	150	115	3	45°	1/8"									
5/8"	5/8"	5/8"	3/16"	150	115	3	45°	1/8"	4	NONE	1/8"	5	NONE	5/8"	6	NONE	1"
5/8"			1/4"	220	160	3	45°	5/32"	4	NONE	5/32"	5	NONE	5/8"	6	NONE	1"
1"	1"	1"	3/16"	150	115	3	45°	5/32"	4	NONE	1/8"	5	NONE	1"	6	NONE	1 1/4"
1"			1/4"	220	160	3	45°	5/32"	4	NONE	5/32"	5	NONE	1"	6	NONE	1 1/4"

CURRENT		STEEL WIRE	
MAX.	MIN	ELECTRODE	FILLER
230	175	1/4"	
290	270		1/4"
220	160	1/4"	

FILLING HOLE 2" DIAM. IN STEEL CASTING (METAL ELECTRODE)

FILLING HOLE 2" DIAM. IN STEEL CASTING (CARBON ARC)

ADDING METAL TO STEEL SURFACE (METAL ELECTRODE)

FIG. 1.

FIG. 2.

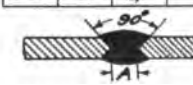


FIG. 3.

FIG. 4.

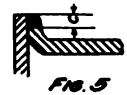


FIG. 5.

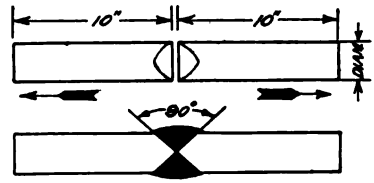
FIG. 6.

K 1800971

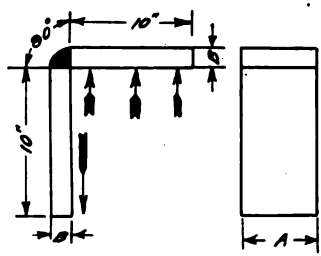
INDEX TO NUMBERS ON WELDED SAMPLES

(BUTT AND RIGHT ANGLE WELDS)

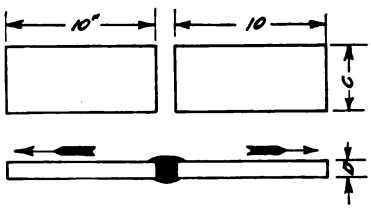
BUTT WELDS				
DIAM.	G.E. METAL ELECTRODE	QUASI	G.E. QUASI	ACETYLENE
1"	1-212	1-113	1-313	1-513
1"	1-213	1-114	1-314	1-514
1"	1-214	1-115		1-515
2"	1-208	1-110	1-312	1-510
2"	1-209	1-111		1-511
2"	1-211	1-112		1-512



RIGHT ANGLE WELDS					
A	B	G.E. METAL ELECTRODE	QUASI	G.E. QUASI	ACETYLENE
1½"	⅛"	2-216	2-116	2-316	2-516
1½"	1/8"	2-217	2-117		2-517
1½"	¼"	2-218	2-118		2-518
1½"	¼"	2-219	2-119	2-319	2-519
1½"	½"	2-220	2-120		2-520
1½"	½"	2-221	2-121		2-521



BUTT WELDS					
C	D	G.E. METAL ELECTRODE	QUASI	G.E. QUASI	ACETYLENE
1½"	⅛"	3-225	3-125	3-325	3-525
1½"	¼"	3-226	3-126		3-526
1½"	⅜"	3-227	3-127		3-527
1½"	½"	3-222	3-122	3-325	3-522
1½"	½"	3-223	3-123		3-523
1½"	½"	3-224	3-124		3-524



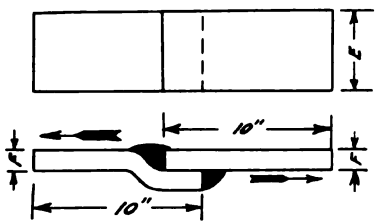
ARROWS INDICATE DIRECTION OF PULL IN TESTING

K 1800972

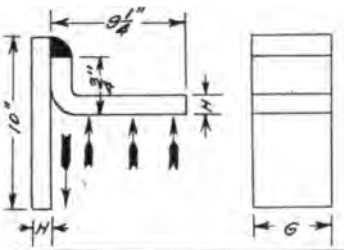
K 1800973

INDEX TO NUMBERS ON WELDED SAMPLES

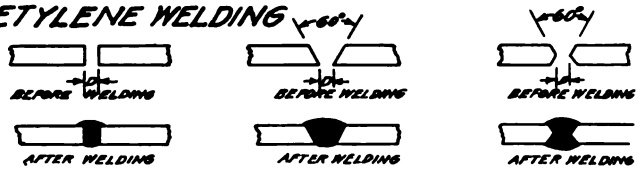
LAP WELDS					
E	F	G.E. METAL ELECTRODE	QUASI	G.E. QUASI	ACETYLENE
1½	1/16	4-231	4-131	4-328	4-528
1½	1/8	4-232	4-132		4-529
1½	3/16	4-233	4-133		4-530
1½	¼	4-228	4-128	4-331	4-531
1½	5/16	4-229	4-129		4-532
1½	⅜	4-230	4-130		4-533



TANK WELDS					
G	H	G.E. METAL ELECTRODE	QUASI	G.E. QUASI	ACETYLENE
1½	1/16	5-237	5-137	5-334	5-537
1½	1/8	5-238	5-138		5-538
1½	3/16	5-239	5-139		5-539
1½	¼	5-234	5-134	5-337	5-534
1½	5/16	5-235	5-135		5-535
1½	⅜	5-236	5-136		5-536



INSTRUCTION SHEET FOR ACETYLENE WELDING



S 1 % EFFICIENCY

S 2 % EFFICIENCY

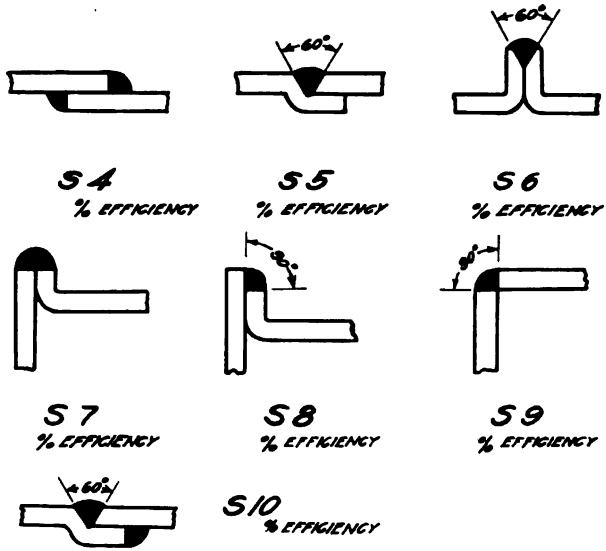
S 3 % EFFICIENCY

THICKNESS OF PLATE	SPACE D	USE METHOD No.
0" TO 1/16"	1/32"	S 1
ABOVE 1/16" TO 1/8"	3/32"	S 1
ABOVE 1/8" TO 1/4"	5/32"	S 1
ABOVE 1/4" TO 1/2"	2/32"	S 2
ABOVE 1/2"	5+1/32"	S 3

NOTE % EFFICIENCY FOR MACHINED WELDS

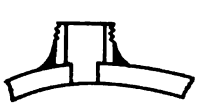
K 1800974

K 1800975

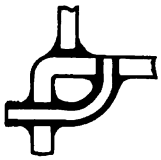


K 1800977

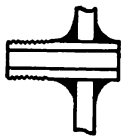
K 1800978



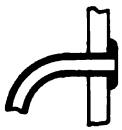
P 19
25 % EFFICIENCY



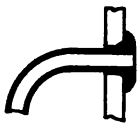
P 20
38 % EFFICIENCY



P21
40% EFFICIENCY

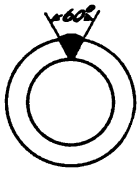


P22
% EFFICIENCY



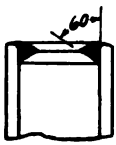
P23
% EFFICIENCY

S 24
% EFFICIENCY

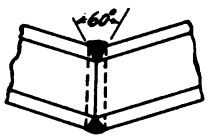


S 25
% EFFICIENCY

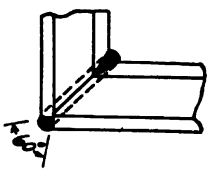
S 26
% EFFICIENCY



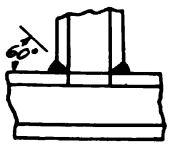
S 27
% EFFICIENCY



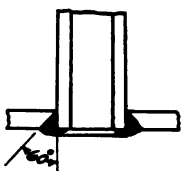
S 28
% EFFICIENCY



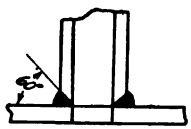
S 29
% EFFICIENCY



S 30
% EFFICIENCY



S 31
% EFFICIENCY



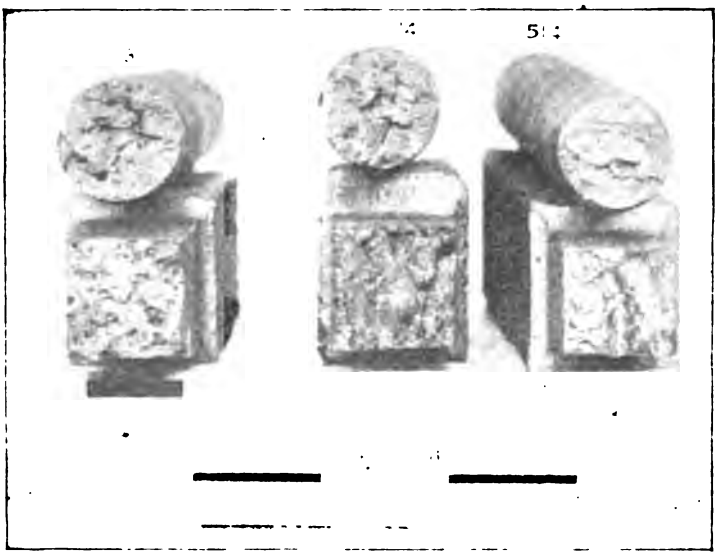
S 32
% EFFICIENCY

K 1800976

107764

Butt Weld in 2″ Steel Bar. Arc Weld at 65 Volts.

113 214 514

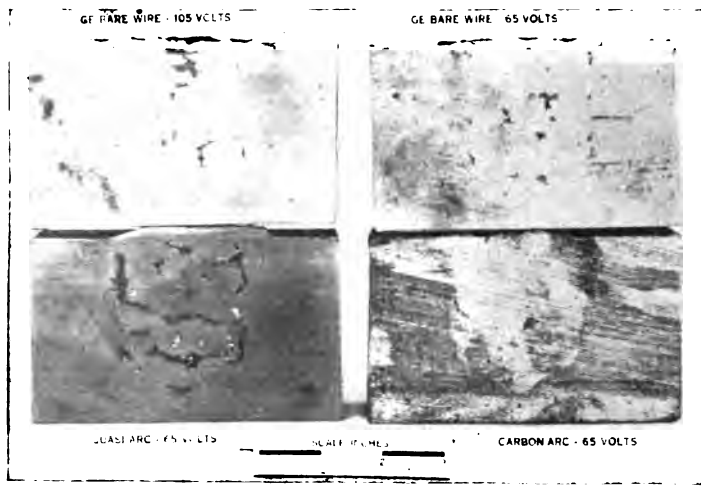


107765 Quasi G. E. Bare Acetylene

Butt Welds in 1 inch Diameter and 1 inch Square Steel Bars.
Arc Welds at 65 Volts.

107766 Quasi Arc G. E. Bare Wire Arc

Filling 2 inch Diameter Drilled Holes in Steel Castings. Welds at 65 Volts.



107767 **Fill 2 inch Diameter Drilled Holes in Machine Steel Blocks.**

G. E. Bare Wire Arc—D. C. 54 Volts.

107768 **Quasi Arc--D. C. 105 Volts** **Quasi Arc—A. C. 105 Volts**

Adding Metal to the Surface of Machine Steel Bars.

G E Bare Wire Arc Butt Welded 225	Acetylene Lap Weld 529	Acetylene Butt Weld 525	G E Bare Wire Arc Lap Weld 232	G E Bare Wire Arc Tank Weld T 15	G E Bare Wire Arc Tank Weld 235	G E Bare Wire Arc Butt Weld

107769

SECTION G:

CONTRIBUTION BY MR. W. J. DELLES, ASSISTANT MANAGER'S DEPARTMENT AT SCHENECTADY WORKS

The attached photographs show booths erected in a separate shop at the Schenectady Works.

Initial instruction was given there by Admiralty Operator Sapper J. M. Muir to six men supplied by Mr. E. E. MacNary to form a nucleus of his elecrtic welding instructional staff.

When installing electric welding in workshops, it is recommended that such isolating booths be provided to prevent operators interfering with each other's work, and also to protect the workmen from the light of adjacent "arcs."

Photo — 109893

Photo — 109894

Photo — 109895

Report No. 18

PROTECTIVE DEVICES FOR ELECTRIC WELDING OPERATORS

The eyes should be protected from the light of the arc by lenses, comprised of one or more each of red and green glass. The number of glasses used depends on the individual. In some cases a total of five glasses have been used. A good rule is to use more glasses whenever the eyes give trouble. A lens of ordinary glass on the outside protects the colored glass from being pitted by the molten metal.

The face, arms and hands should also be protected, otherwise they will have the symptoms of severe sunburn. The masks protect the face. Clothing should be worn to protect the hands and arms.

Below is a table referring to photographs of several types of masks. Masks No. 2 and No. 4 are preferred at the General Electric Company, Schenectady, N. Y. The shape should be such that but little light can come in from behind, as it interferes with the view of the work. These masks are of aluminum with the clamps so arranged that at least six glasses may be placed in the window.

	Front View	Rear View
1. **Shield**—A slightly curved hand shield		1
2. **Mask**—A semi-ellipsoid		2
3. **Mask**—A larger view of the mask described above	3	4
4. **Mask**—A flat surface mask	5	6
5. **Helmet**	7	
6. **Helmet**	8	

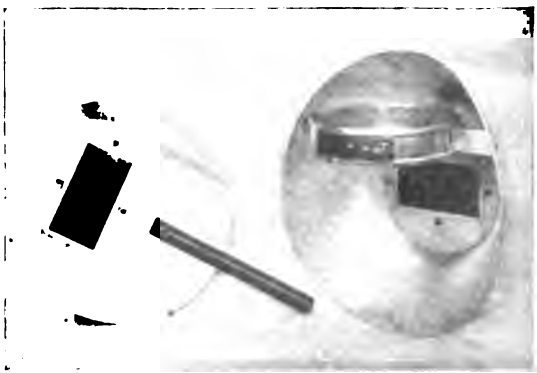


Fig. 1 Fig. 2

Fig. 3
Front View

Fig. 4
Back View

Protective Devices for Electlic Welding Operators

Fig. 5
Front View

Fig. 6
Back View

Protective Devices for Electric Welding Operators

Fig. 7

Fig. 8

Electric Welding Helmets

Report No. 19

ELECTRIC ARC WELDING COMPARATIVE DATA—COST & CURRENT REQUIREMENT WITH BARE AND FLUX-COVERED METAL ELECTRODE

Compiled by

CHESTER SHIPBUILDING COMPANY
RESEARCH & EXPERIMENTAL DEPARTMENT

I am indebted to Mr. J. G. Dudley for the following information, which he obtained as a result of recent tests.

Thickness of Metal and Electrode		Cost of Electrode Per Ft. Weld	Labor at $0.50 per hr.	Current at $.01115 per KW	Total Cost Per Ft. Weld
1/16"	Slag Coated	$0.02	$0.0125	$0.000854	$0.03335
1/16"	Uncoated	.00472	.025	.001449	.031169
1/8"	Slag Coated	.03	.02083	.001428	.05225
1/8"	Uncoated	.00918	.03125	.002996	.04342
3/16"	Slag Coated	.05	.025	.003213	.078213
3/16"	Uncoated				
1/4"	Slag Coated	.06416	.025	.004291	.09345
1/4"	Uncoated	.03255	.05	.009589	.092139
5/16"	Slag Coated	.0725	.05	.007721	.13022
5/16"	Uncoated				
3/8"	Slag Coated	.1075	.06666	.010213	.18437
3/8"	Uncoated	.05816	.07692	.018354	.153434
7/16"	Slag Coated	.155	.08333	.012873	.251203
7/16"	Uncoated				
1/2"	Slag Coated	.185	.0909	.013972	.28987
1/2"	Uncoated	.09281	.11628	.031116	.240206
5/8"	Slag Coated				
5/8"	Uncoated	.13464	.17857	.05336	.36657

NOTE: Cost of AIR to drive rivets based on four rivets per ft. Amount of AIR to drive one rivet after steel is set up = 90 cu. ft. at 100# pressure = 15 HP at $0.01115 per KW = $0.1247 x 4 rivets per foot = $0.4988. This does not include LABOR for drilling, punching or assembling.

Report No. 20

NEW YORK NAVY YARD INVESTIGATIONS OF ELECTRIC WELDING

A—Tests by Bureau of Steam Engineering
B—Tests of Quasi-Arc System
(1) Tests by Machinery Division
(2) Tests by Hull Division
(3) Description of Outfit

SECTION A: ELECTRIC ARC WELDING—REPORT OF TESTS MADE AT NEW YORK NAVY YARD
By Direction of
BUREAU OF STEAM ENGINEERING
SEPTEMBER, 1917.

1. Tests have been under way in the testing laboratory during the past year on various types of electric welding outfits. Tests have actually been conducted on the following outfits: Siemund-Wenzel, C. & C. Electric Co., Westinghouse Electric & Manufacturing Co., Wilson System, as used by Erie Railroad Co., Federal Electric Welding Co., and in addition the following have been investigated and considered: Electric Welding Co., the Quasi-Arc Weldtrode Co. The different systems investigated and tested are described in detail later in this report. There may be other outfits on the market, but it is believed that all the principal ones and at least all the different types, have been considered. Of the various radically different systems of electric arc welding, it is believed that the Slavianoff system alone merits serious consideration for general work. This system is based upon the use of a metallic pencil as the negative electrode (or cathode), and the article worked on as the positive electrode (or anode), and the use of continuous current at low voltage.

2. The quality of the weld obtained is dependent on the following: First, the skill of the operator. Second, furnishing the correct amount of energy at the weld for obtaining the proper working temperatures of the material to be welded. Third, the quality of the metal electrodes (the welding wire).

3. **The Operator**—A certain amount of skill and experience is required of the operator, no matter what system of electric welding may be used, but some types of outfits require much more skill and closer attention than others; and it is considered essential that the ideal system should require a minimum of experience and only normal mechanical skill. A system which depends primarily on the skill of the operator cannot turn out consistent work and is not suited to the navy's use.

4. **The Correct Amount of Energy**—The material worked on, the anode, is heated by the impinging of the cathode stream; by the joulean heat developed by the ohmic contact resistance; and by the radiant heat given off by the arc, the metallic pencil, or cathode, is heated by the joulean heat due to its ohmic resistance to current flowing and by the slight con-

tact resistance at the electrode surface. The greater proportion of the heat generated at the arc is at the anode, or material being welded (approximately 75 per cent of the total heat), when the metallic arc is used. This is quite satisfactory, due to the greater means of dissipation at the anode by radiation, convection, and conduction. Practically all the energy supplied to the arc is dissipated as heat, only a slight proportion being given off as light; and to regulate the amount of heat units, and thereby the temperature of a particular shape and class of material, it is essential to regulate the amount of energy supplied to the arc as measured in watts. The maximum temperature of steel in the usual converter is approximately 1,800 degrees C., the melting point being approximately 1,400 degrees C.; the temperature of boiling steel at atmospheric pressure is approximately 2,450 degrees C., while the temperature of the arc stream may greatly exceed this. The result is that in electric arc welding, steel is being worked near a critical temperature. The material to be welded should be in a plastic state sufficient for the proper intermixing of the metal and obtaining of perfect fusion; if the temperature is too low the added material will not adhere to the original metal, and the weld will fall apart at the surface; on the other hand, if too high a temperature is obtained, the metal will be burned and the weld will be greatly weakened by the slag thus formed and will be of coarse and irregular structure. The safe working temperature depends somewhat on the material to be welded, and the operator quickly obtains the necessary experience to tell if he has the proper temperature. The amount of energy necessary to obtain the proper temperature at the weld depends upon the size and shape of the piece worked on, it being the amount of energy necessary to supply the heat losses and keep the weld constantly at the proper welding temperature. The amount of energy required varies as the whole mass of the article becomes heated, a greater amount being required at first when the mass is cold; for this reason it is important in order to obtain consistent results to have a control of the energy at the operator's end of the line. This control should require very few changes in the supplied energy and is not to overcome the variations of energy due to changes in arc length. The temperature at the weld should remain practically constant; a momentary inrush of current will burn the metal at that point, and cause a flaw, with the chances of reducing the tensile strength of the weld 50 per cent or even more.

5. **Electrodes**—There are two methods of electric arc welding—one, the Bernardos process, in which a carbon electrode is used; and the other, the Slavianoff process, in which the metallic electrode is used. As a result of the tests which we have conducted, and from the experience of others in elec-

tric arc welding, it is believed that the carbon electrode process is not suited for general work, some of the reasons being that much greater difficulty is experienced in maintaining the proper temperature, and there are more chances of getting an excess of carbon in the weld. In the Slavianoff process, which is nearly universally used at present, it is necessary to have metal electrodes of such material that the deposited metal in the weld shall have practically the same characteristics as the rest of the metal of the object worked on. As certain of the constituents of the electrode are partially lost in the arc, it is usually necessary to have the electrode contain an excess of certain materials over what is desired in the finished weld. The amount of the loss of these constituents depends upon the temperature, and it is necessary in order to obtain desired and consistent characteristics in the finished weld to have a constant temperature at the weld. The steel companies will guarantee the results with the electrodes which they supply only if the system of the welding with which they are used can maintain a constant temperature at the weld.

6. **Fluxes**—Certain companies claim that a flux is necessary to obtain good results, but in the tests conducted all sorts of material and in all positions have been welded, and the best results have been obtained from systems in which no flux is used. The claim in favor of the flux is that it blankets the weld by forming a gas around the material, which prevents oxygen reaching it and thereby prevents oxidation. This has been proven not necessary, by making similar welds first where oxygen was entirely excluded and then under normal conditions in the air, and there was no difference in strength or structure of the weld. Another claim is that the flux acts as a scavenger to remove the impurities from the weld. It cannot act in this way unless the metal actually boils, and this is a condition which, as previously shown, should be avoided. There are also certain users who believe a flux necessary for overhead work, but, in tests conducted, as good and consistent welds were obtained when welding overhead without a flux as in any other position. It is considered that in a good electrical welding system a flux is not necessary and simply an added expense and complication.

7. **Equipment**—The necessary equipment should consist of a flat compounded interpole motor generator set (a slight overcompounding is desirable if induction motor is used), the armature winding being insulated with mica to prevent rupturing of insulation when arc is broken; usual control apparatus for motor generator; control for each welding circuit; electrode holders; protective coverings for the operator; necessary metallic electrodes; and carbon electrodes for cutting. It is believed that a two-welder equipment, with a continuous rating of 300 amperes is most satisfactory for general use in the

navy. At a later date, as its advantages become more recognized and its uses become better known, it is probable that large equipments will be necessary in shops, etc.

8. **Automatic Control**—While it is recognized that it is desirable to have as simple an equipment as possible, it is considered necessary to have an automatic control of the input energy to the weld (the reasons for which have been previously mentioned) so that when the proper amount of energy has been determined for a particular job it will remain constant regardless of the varying of the arc length. A system with fixed resistances depends entirely on the skill of the operator in maintaining his arc length constant and thereby the energy constant. This system gives good results at times, but our tests showed that even with a skilled operator, furnished by the manufacturer, tensile strengths varying as much as 50 per cent on the same class of material were obtained. It should be possible for the operator to set the current controller at the desired amount as well as at the panel board; the controller should automatically keep the current approximately at the fixed value. A variation of less than 5 per cent can be obtained with a well-designed equipment.

9. **Cutting**—The electric arc has been found suitable for cutting, but a carbon electrode must be used; no automatic current control is necessary, although a choke coil is advisable, to prevent large inrushes of current. The amount of current varies with the size of the material to be cut; from 250 to 400 amperes are required for burning of rivet heads and light section plates, while from 600 to 800 amperes may be required on plates 4 inches thick. This is a momentary load, however, and a 300-ampere continuous-duty machine is considered sufficient. It is necessary to cut away the edges of the cut and remove the burnt metal.

10. **Preparation of Material to Be Welded**—The material to be welded should be cleaned with a scraper or wire brush to remove oxides and prevent forming of slag; and it is also necessary to bevel the edge sufficiently so that the distance from the electrode to bottom of the weld is less than that of the electrode to any other part of the article, so that the arc will not stray. In thick plates, where possible, and especially in castings, it is usual to weld from both sides, and in this case the original material is pointed by beveling on both sides.

11. **Applications of Arc Welding.**—During the past year this yard has had contract electric welding done on boilers of various ships. Certain defective castings have been welded, blow-holes filled in others, and miscellaneous repair work has been done while the various machines were under test. Additional uses are being developed as the advantages of this method become better known. A large saving in cost over other methods of repair has been made on boiler jobs, in

addition to a saving in time, notwithstanding the large profit which the outside contractors have made on the jobs. A specific application of arc welding is in the making of high-speed tools. The tool is made of ordinary steel, and high-speed tool steel is used for the cutting edge only.

Some of the various applications are as follows: Building up of work, wearing parts, pins, rollers, bearings, etc.; welding of plates in lieu of riveting, or where seams are leaking; building up of rivets; building up of stripped gears; repair of cracked castings; making of high-speed tools; filling blowholes. In manufacturing work: Welding of heads on tanks; welding of tubes in tube sheets; welding of feet and end frames, etc.

Brass, bronzes, and aluminum, as well as steel, cast steel, wrought iron, cast iron, can be welded, but none of the demonstrators have been able as yet to get very high tensile strength on naval brass.

12. **Special Application for the Navy**—Electric arc welding is considered especially applicable for use on shipboard for emergency repairs of all sorts. In this connection it may be noted that the British cruiser Glasgow put in to Rio de Janiero after the battle off Chile with several holes below or near the water line, was able with an arc-welding set, which happened to be in Rio de Janiero, to weld plates over the holes inside of 24 hours and put to sea, taking with them the arc-welding set. It is considered that all first-class ships should be equipped with electric arc-welding outfits of some description in addition to sets on the repair ships.

DESCRIPTION OF ARC-WELDING SETS SUBMITTED FOR TEST

1. **C. & C. Electric & Manufacturing Co.**—The apparatus consists of a special direct-current generator wound for the proper welding voltage and amperes. The generator and motor are mounted on a common bedplate provided with four wheels and pulling handle. The motor starter, generator field rheostat, and control panel are mounted on the common bedplate, making the entire outfit portable and readily wheeled into any desired location on a ship. The chief distinction of this outfit is the automatic series contactors. These automatically reduce the current in one step upon the application of a short-circuit produced by striking the arc. Upon drawing the arc to the operating distance the contactor cuts out resistance to a predetermined section of the dead resistance. Excessive overloads are provided for by a series contactor which cuts in resistance until the current is reduced, whereupon the resistance is again automatically cut out. The motor is furnished suitable for the particular requirements and has no bearing on the welding scheme.

2. **Westinghouse Electric & Manufacturing Co.**—This apparatus consists of a compound-wound generator driven by a direct-coupled motor mounted on a common bedplate. Both the Bernardos and Slavianoff processes are used, the former being used for heavy pieces and the latter for lighter work. The current of the system is regulated by series resistances operated in steps by single-pole non-automatic switches. The system requires that the operator maintain a constant arc length, as the current is not maintained at a constant value other than that furnished by the regulation of the generator. Short-circuiting is prevented by a fixed dead resistance, and excessive overleads are prevented by a single-pole overload circuit breaker which requires to be closed by the operator after functioning.

3. **Wilson Electric Welder as Used by the Erie Railroad.** This outfit consists essentially, of a constant voltage generator driven by any constant-speed motor, all mounted on a common bedplate. The regulation of the welding current is maintained by means of a series carbon pile acting as a series resistance of varying quantity under the action of increasing or decreasing mechanical pressure. This pressure is produced by means of a series solenoid operating mechanically on a lever and spring system which varies the pressure on the carbon pile inversely as the current in the main circuit. This establishes a constant current balance at any predetermined adjustment between a maximum and minimum range designed for. This change in adjustment is controlled by the operator at the point of work by means of a small pilot motor which shifts the lever center of the pressure mechanism, thereby raising or lowering the operating current. This system maintains a constant predetermined current at the arc regardless of the arc length. The operation of the mechanism is positive and quick acting. A special series choke-coil is mounted on the control panel for use as a cutting resistance.

4. **Siemund-Wenzel System**—This system consists of the usual constant-voltage generator driven by a motor or engine. The principal feature of this system lies in having the generator operating at full load all of the time and using the current in the arc when welding, or dissipating the energy through a resistance by means of a solenoid switch. The disadvantage of this system lies in its low efficiency, due to continuous load on the generator when not actually welding.

5. **The Federal Electric Welding Co.**—This system embodies the usual constant-voltage generator and constant-speed motor mounted on a common bedplate containing also the control panel, with meters and relays. The current is controlled from excessive values by a series relay which cuts in generator field resistance, thereby reducing the generator voltage to a safe value.

6. **The Quasi-Arc Weldtrode Co.**—This system was not submitted for examination or demonstration. This scheme, however, requires the use of special fluxes in addition to the usual arc current. It has been clearly demonstrated that successful and reliable welds can be provided without the use of fluxes. Fluxes complicate the operation, increase the cost of materials, and are generally undesirable.

7. **The Electric Welding Co.**—This system consists of a flat compound generator, with a motor drive as required. The scheme used is that of a constant-current regulation device on the generator. One or more welding circuits are placed in series, and the constant current is regulated through the system in connection with a small fixed series resistance by means of an automatic field regulator. The regulator increases or decreases the generated voltage and balances the change in line resistance due to varying arc lengths. This system is not considered to be practical for ship use, as each welding operator could work only on insulated work. A grounded section would cut out or shunt the succeeding sections.

TENSILE STRENGTH TEST

Welding Manufacturer	Sample No.	Area of Cross Section in Square Inches	Strain per Square Inch in Pounds	Limit of Elasticity in Pounds	Per Cent. Elongation
Stock flat steel	1	0.235 by 1.0	46,930	32,890	13.8
Do	3	.257 by 1.0	59,840	31,120	30.0
Westinghouse Elec. & Mfg. Co.	1	.227 by 1.0	23,780	22,020	.3
Do	2	.171 by 1.0	35,670	23,390	.9
Do	3	.182 by 1.0	45,930	21,970	8.9
Navy Yard Acetylene Gas	1	.200 by 1.0	34,400	32,000	2.1
Do	2	.207 by 1.0	31,830	31,830	1.3
Siemund-Wenzel Elec. Welding Co.	1	.312 by 1.0	57,660	.....	2.0
Do	2	.312 by 1.0	42,040	.....	8.0
C. & C. Elec. & Mfg. Co.	1	.34 by 1.0	52,345	.....	6.25
Do	2	.....	.....	.....	.....
Erie Railroad	1	.500 by 1.25	47,770	28,880	15.0
Do	2	.500 by 1.25	47,000	28,400	10.5
Federal Elec. Weld. Co.	[1]1	.....	.....	.....	.....
Do	[1]2	.....	.....	.....	.....
Stock round steel	1	0.505d	91,600	51,250	16.0
Do	2	.505d	91,250	50,250	14.5
Westinghouse Elec. & Mfg. Co.	1	.505d	[2]27,550	14,520	4.0
Navy Yard Acetylene Gas	1	.505d	53,550	31,200	7.0
Do	2	.505d	46,850	25,620	6.0
Siemund-Wenzel Elec. Welding Co.	1	.505d	41,000	.....	.....
Do	2	.505d	44,000	.....	.....
C. & C. Elec. & Mfg. Co.	1	.505d	39,750	20,250	5.8
Erie Railroad	[1]1	.....	.....	.....	.....
Do	[1]2	.....	.....	.....	.....
Federal Elec. Weld. Co.	1	.505d	46,575	40,500	3.5
Do	2	.505d	40,450	40,500	4.0

[1]Samples not received. [2]Defective.

SECTION B: REPORT OF TESTS OF QUASI-ARC SYSTEM MADE AT NEW YORK NAVY YARD

1. The Quasi-Arc Weldtrode Co. (Inc.), sent representatives with equipment to this yard for a demonstration of the Quasi-arc methods for electric welding. The following demonstrations were made in the machine shop of the machinery division for the engineer officer:

2. A large casting for the throttle valve of the U. S. S. AGAMEMNON and two brackets for boat cranes for the U. S. S. NEW MEXICO were repaired. The throttle valve for the AGAMEMNON had a bad crack in the neck of one of the connections, and a blow-hole on the outside near one of the flanges of about 1¼ inches diameter and approximately the same depth. The crack was chipped into in order to get deep enough into the metal to make welding effective. The blow-hole was welded without any chipping having been done and was filled up with solid metal from the bottom. The holes in the brackets for the boat cranes were blow-holes in the bearings, and were filled up in the same manner as the blow-hole in the throttle valve. The metal in both cases was cast steel, and the metal that was welded and the metal around the weld remained soft so that it could be machined without difficulty.

From the experience gained in electric welding in the machinery division, it is considered that all these welds were entirely satisfactory. In addition three specimens were welded, one of cast steel, one of rolled steel, and one of cast iron, and were later pulled and examined with the results included in Appendix 1. (Pages 379-389). Appendix 1 is considered complete and requires no comment. The following points, nevertheless, should be noted:

That in the case of cast steel an elongation of 6.5 and in the case of rolled steel an elongation of 8 per cent in 1 inch was obtained. This was considered excellent for a welded specimen. It also should be noted, as shown in figure 3, that the heat from the arc extends for about 1 inch from the weld, which might cause a slight distortion in certain cases of welding of the finished, machined product.

Appendix 2 (page 390) is tabulated data obtained as the result of test pieces welded for the hull division. The test

pieces in question were selected from a number of various types of welds made at this yard on August 8, 1917. The metals tested were the only ones having a shape and size suitable for testing, the remaining test pieces consisting of angle welding, shape welding, etc., which do not readily adapt themselves to testing. It is to be noted that in one of the test pieces the steel plating used was taken from a different delivery of steel plates than the plate tested for strength without weld. Different deliveries of plating will vary in tensile strength. It will also be noted that some of the test pieces are considerably lower in strength than others of the same type and size, the difference being due to imperfect welds, which are burned or only partially welded.

3. The following comment is submitted:

Electrical equipment as described in Appendix 3 (page 391) is simple, inexpensive and light, and the current required is available at any yard or on any ship of the navy. The covering of asbestos on the weldtrodes permits this system to be used to fill from the bottom, deep holes or crevices, without chipping out a large amount of metal, as when using the bare electrodes an arc forms from the electrode to the metal, whereas with the quasi-arc weldtrode the covering of asbestos prevents this. From the demonstration given it is believed that the efficiency of the weld is equal to the efficiency of other methods of welding that have been used at this yard. The method was not tried for welding vertical surfaces and it is believed that certain difficulties would be encountered for this method of welding. This point through an oversight was not brought up with the quasi-arc demonstrators. The manager recommends that an outfit with a limited amount of weldtrodes be purchased for use of this yard in order to get a thorough trial and comparison with the other methods of welding already in use. This is recommended in view of the increasing amount of work on which the electric arc welding is being used, in order, if possible, to get complete data as to the best method under various conditions for welding work.

SECTION B—APPENDIX 1: RESULTS OF TESTS OF QUASI-ARC SYSTEM BY MACHINERY DIVISION NEW YORK NAVY YARD

Per DR. WILLIAM CAMPBELL (Metallurgist)

TENSILE TESTS OF THREE WELDS BY QUASI-ARC METHOD.

No. 32. Steel, cast. Tensile strength, 37,500 pounds. Elongation, 6.5 per cent in 1 inch.

No. 33. Steel, rolled. Tensile strength, 49,200 pounds. Elongation, 8 per cent in 1 inch.

No. 34. Cast iron. Tensile strength, 17,200 pounds.

(See Photographs Pages 382-389.)

No. 32—Made From Steel Casting.

The general appearance of the weld is shown in Fig. 1. The weld metal is full of small globules of slag, but is not very much dirtier than the original steel. Grain fine. The steel has been heated a considerable distance back. At one side the lower critical point (say 730° C.) Ac_1 occurs at 0.9 inch from the fracture, while at the other side it occurs at 12 inches from the point of fracture.

Fig. 1 (x90.) Shows the structure of the original steel at (k). Rather coarse grain. A good deal of manganese sulphide and oxide in the ferrite. (Page 383.)

Fig. 2. At (a). The metal has just reached the lower critical point, Ac_1 and the dark pearlite has started to refine. (Page 383.)

Fig. 3. At (b). The metal has reached a temperature somewhere between Ac_1 and Ac_3 (between 730° and say 825° C.). Some ferrite remains unrefined. (Page 383.)

Fig. 4. At (c). Refining practically complete. Grain very fine. A faint outline of ferrite cell wall is seen. This persists because it is richer in phosphorus than the rest of the original grain. (Page 383.)

Fig. 5. The weld at (c). The left-hand lower corner shows the steel, a trifle coarser in grain than the last. The upper right-hand is the weld metal, fine grained, low in carbon, with one or two small dots of slag. The weld is perfect. (Page 384.)

Fig. 6. The weld at (f) is similar. (Page 384.)

Fig. 7. The weld metal at (e). Low carbon with a peculiar spicular structure. Grain small. A few dots of slag. The second print gives more contrast. The other half of the weld is similar. (Page 384.)

Fig. 8. At (l). The original steel just at the lower

critical point (say 730° C|). The dark pearlite has refined. (Page 385.)

Fig. 9. At (g). The upper critical point (say 825° C.) has been passed and the metal is refined. Dark spots and veins are manganese sulphide, etc., and segregated areas (ghosts). (Page 385).

Fig. 10. The weld at (h). Junction perfect. The weld is very good. The few slag globules that occur in the weld metal are unimportant. The heat has traveled back farther than in the welds already examined (Wilson and Navy Yard). (Page 385.)

No. 33—Made From Rolled Steel.

The general appearance of the weld is shown in Fig. II The weld metal is similar to the last, but at Z is slightly oxidized. One or two porous spots occur at V. At the CD side the grain is small and granular (Fig. 16); at X it is spicular (Fig. 7). The steel has been heated back a considerable distance. The lower critical point (say 730° C.) occurs at 1 inch from the fracture. At Y a few coarse grains appear.

Fig. 11. Shows the original steel at (f). Fine grained and somewhat laminated. (Page 386.)

Fig. 12. At (a). The lower critical point, Ac_1, has just been passed and the pearlite is refined. (Page 386.)

Fig. 13. At (b). Shows the weld. The fine grained weld metal is on the right upper corner, the steel at the left lower part. The steel has coarsened considerably compared with the last sample, but not dangerously so. (Page 386.)

Fig. 14. At (c). Is similar. The steel is somewhat coarse which tends toward brittleness under shock. (Page 386.)

Fig. 15. At (d). The weld also. The weld metal shows one or two globules of slag. (Page 388.)

Fig. 16. The weld metal at (e). Fine grain, very low carbon. This shows the largest of the slag globules. (Page 388.)

The weld is good, though not quite so perfect as the last, yet its strength is greater. As before the heat has traveled back, about 1 inch on each side up to 730° C.

No. 34—Made From Cast Iron.

The zoned structure is shown in Fig. III. The weld metal varies from low carbon to very high, showing free cementite (carbide). The weld itself shows a layer of material like semi-steel. A very fine grained mixture of ferrite and pearlite with a small amount of minute graphite flakes. This is much preferable to the white cast iron found in the Wilson and Navy Yard welds. The cast iron has been heated back as in the other samples and shows similar changes in structure to those found in welds already examined.

Fig. 15a. (Page 387.) Shows the original cast iron at (a). Black plates of graphite, in a matrix of pearlite in which

a little of the phosphide eutectic occurs as veins. The white patches are ferrite associated with the graphite.

Fig 16a. At (b). The structure has completely changed. The metal has been heated above 730° C., and the steel matrix shows refining. Graphite as before, the phosphide eutectic remains unchanged, but the matrix is now a very fine mixture of ferrite and sorbitic-pearlite. (Page 387.)

Fig. 17. At (c). Very near the weld. Graphite and phosphide as before. Matrix of sorbitic-pearlite. Ferrite has precipitated on the graphite. (Page 387.)

Fig. 18. At (e). The weld. The lower left-hand corner is the cast iron. Next comes a zone of material like semi-steel. Then a band of high carbon steel pressing into lower carbon at the upper right-hand corner. The junction is perfect. (Page 387.)

Fig. 19. At (f). The weld. Slightly repolished to bring out the structure. Is similar to the last. The tiny veins of carbide show up next the weld, in the weld metal. (Page 388.)

Fig. 20. At (g). The cast iron in the lower right corner. The weld metal is mostly high carbon steel, with a good deal of carbide, but not so brittle as the white cast iron found in the other welds of cast iron. (Page.388.)

Fig. 21. The weld metal at (d). Junction between a low and a high carbon area. (Page 389.)

Fig. 22. Near (a). Toward the outside. Repolished slightly. Black plates of graphite. Veins of phosphide eutectic in a matrix of granular pearlite. A little ferrite associated with the graphite. The metal has barely reached the critical point. (Page 389.)

Fig. 23. At (k). The coarse ferrite has been absorbed and the matrix is now a fine mixture of ferrite and sorbitic pearlite. (Page 389.)

Fig. 24. The weld at (h). Fracture occurs at the junction of the "semi-steel" and the high carbon weld metal. This is typical of the fracture which follows this junction for the most part. (Page 389.)

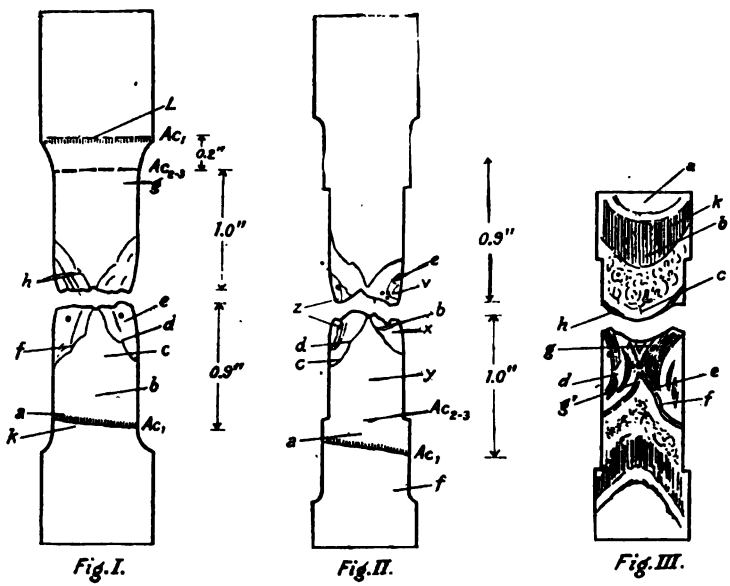
The weld is very good. It shows no layer of white cast iron as in the Navy Yard and Wilson welds, and from the point of view of structure is preferable. It heats farther back than they do, however.

Summary

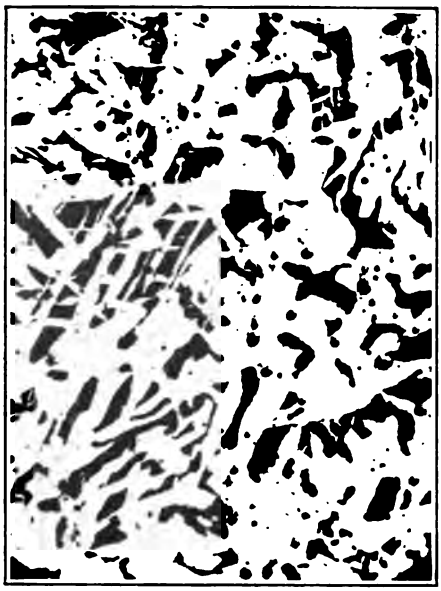
(1) The welds all show an excellent structure.

(2) The cast iron is better than those previously examined.

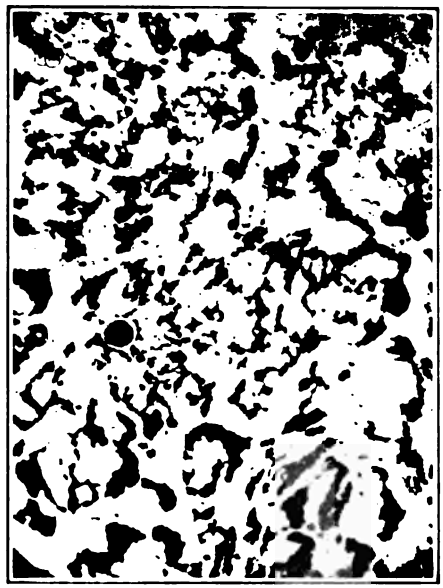
(3) All show metal to have been heated farther back than the previous welds, the depth of the refining point (Ac_1) or lower critical point (say 730° C), being about 1 inch from the fracture.



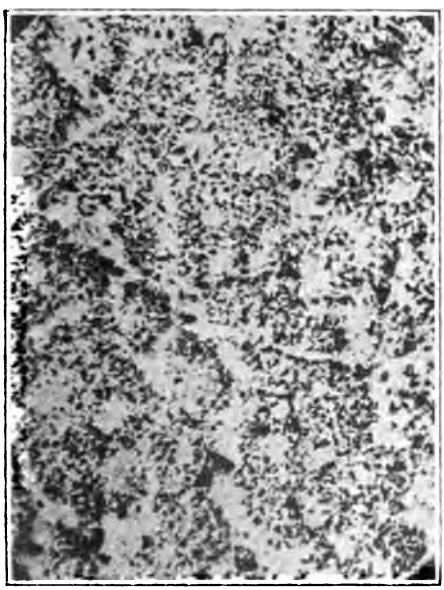
Three welds by quasi-arc method.



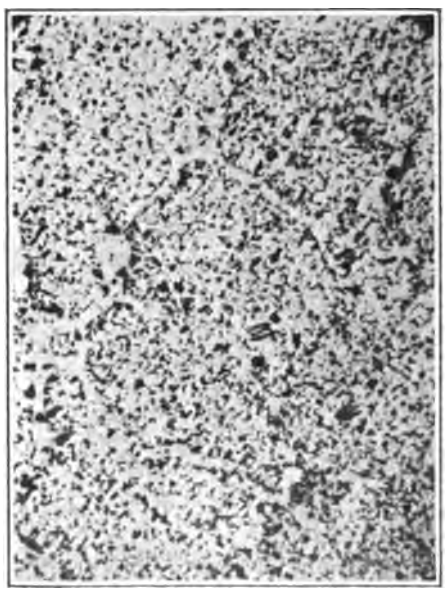
1 At k



2 At a

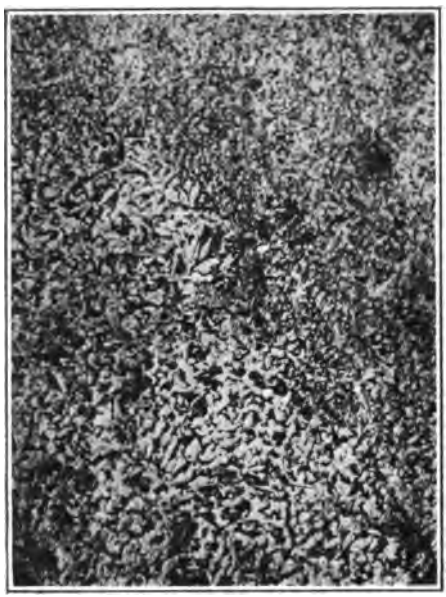


3 At b

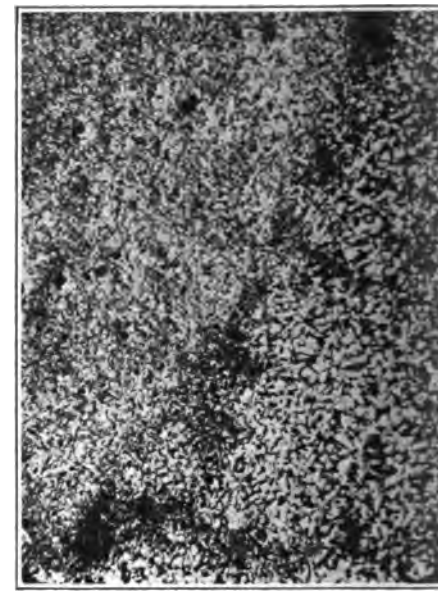


4 At c

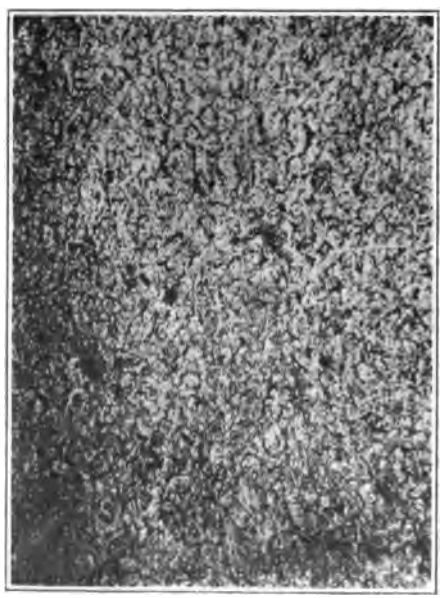
WELD No. 32, QUASI, A ROLL STEEL CASTING, X 90



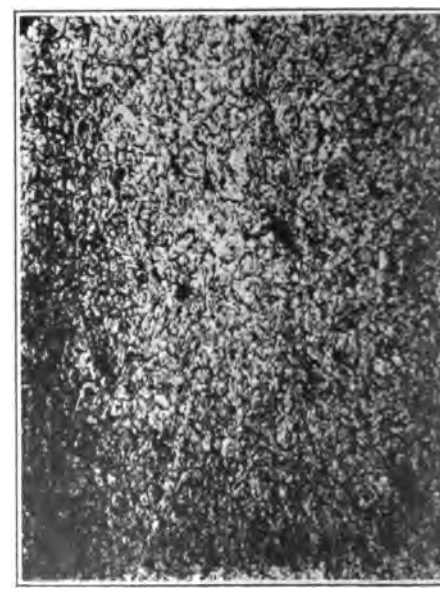
5 At d



6 At f

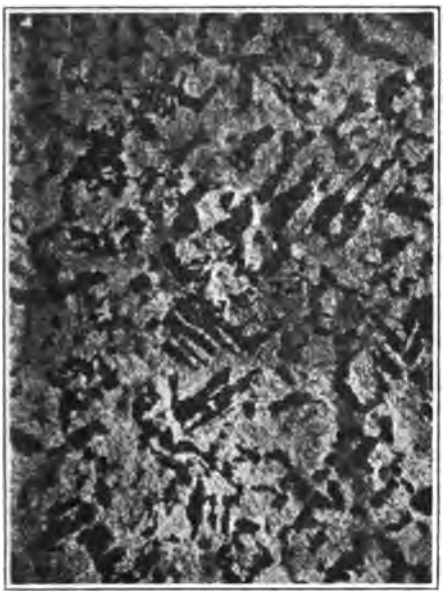


7 At e

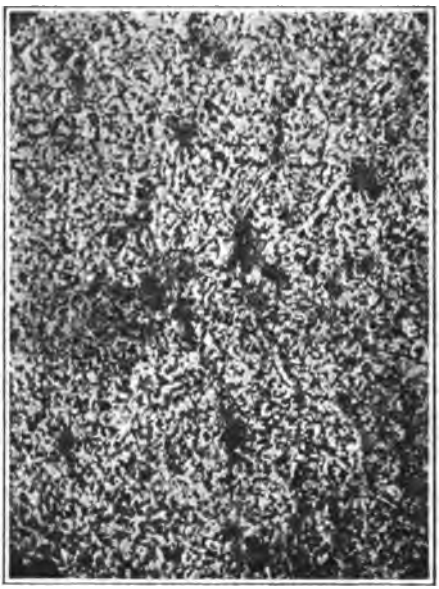


7 At e, deeper print

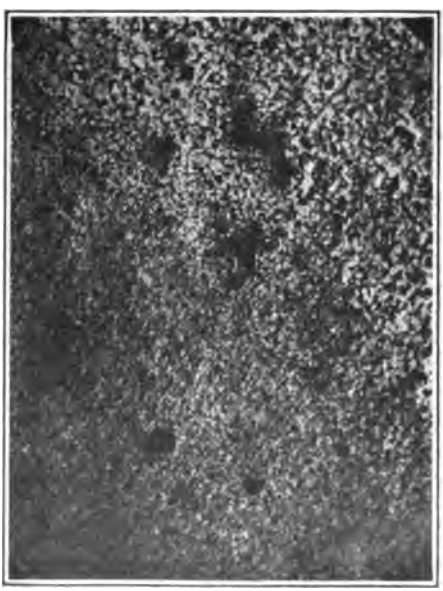
WELD No. 32 X 90



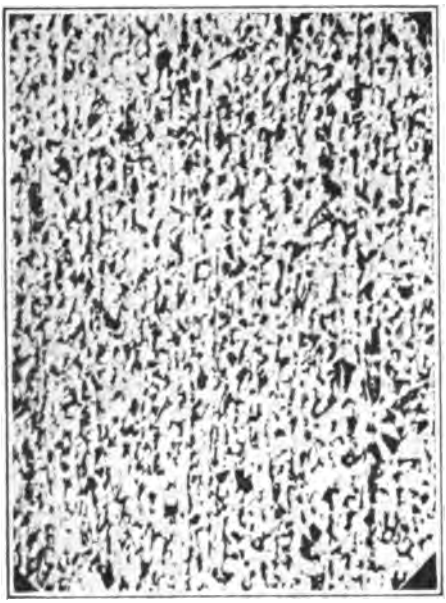
8 At l



9 At g

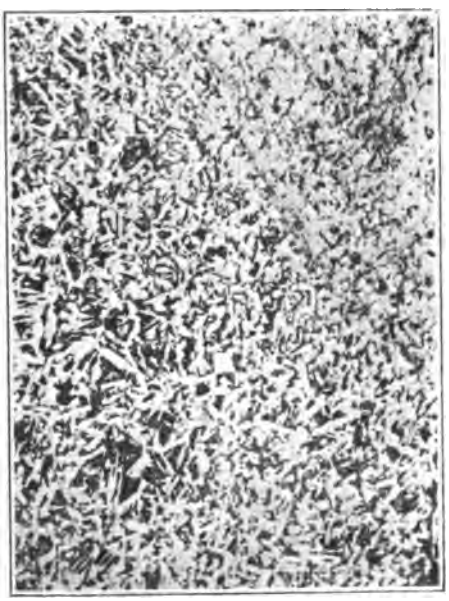


10 At h
WELD No. 32 X 90

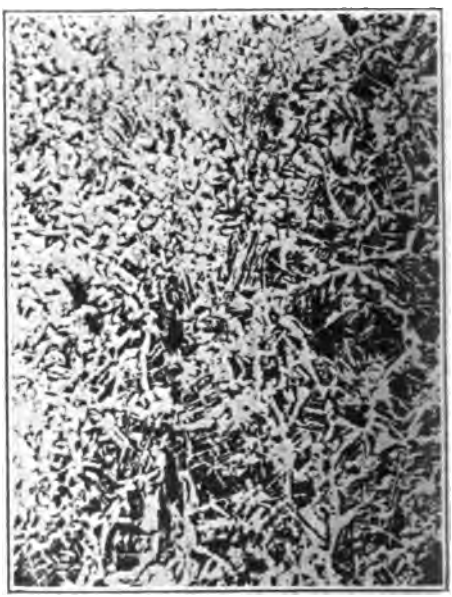


11 At f

12 At a



31 At b



14 At c

WELD No. 33 ROLLED STEEL, X 90

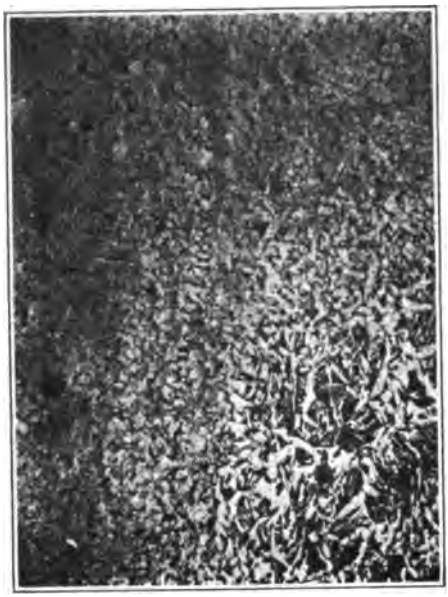
15 a. At a

16 a. At b

17 At c

18 At e

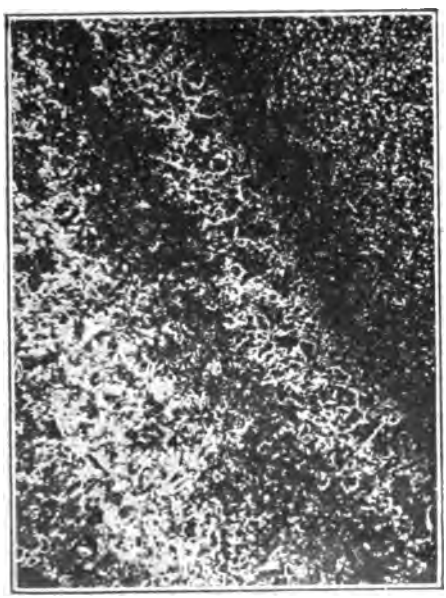
WELD No. 34, CAST IRON, X 90



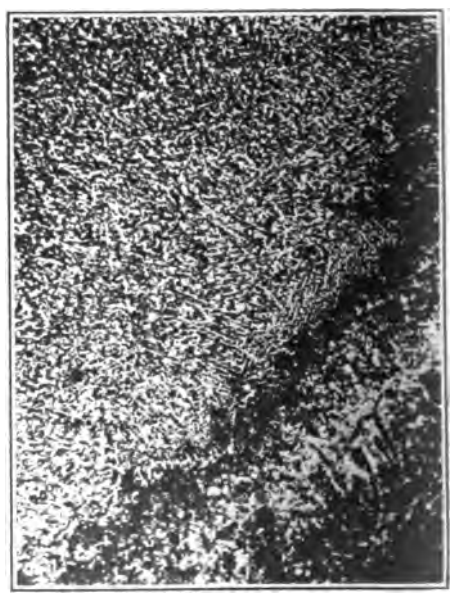
15 At d

16 At e

WELD No. 33 X 90



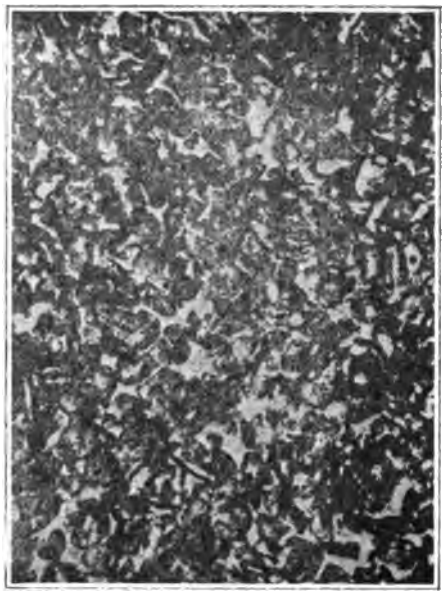
19 At f Repolished



20 At g Repolished

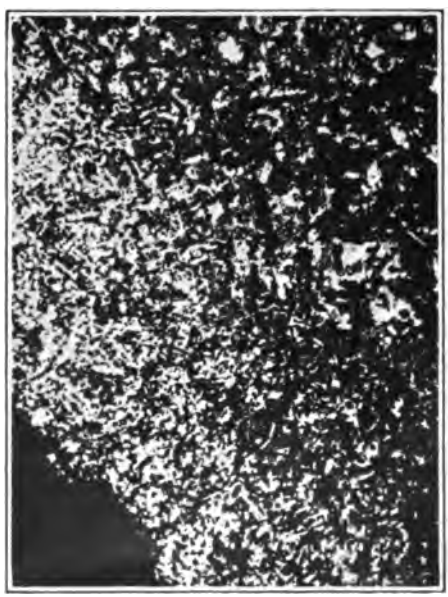
WELD No. 34 X 90

21 At d



22 Near a. Toward side. Repolished

23 At k. Repolished



24 At h. Repolished

WELD NO. 34 X 90

APPENDIX 2—RESULTS OF TESTS OF THE QUASI-ARC SYSTEM BY HULL DIVISION, NEW YORK NAVY YARD, NEW YORK.

Appendix 2

Results of Tests.— Quasi Arc System
by
Hull Division N.Y. Navy Yard, N.Y.

No.	Type	Width	Pull	Pull per inch Width	Efficiency	Power Required				Time Required to Weld 1 Foot (Hours)	K.W. Hours Per Foot Weld	Power Cost of Weld Per Foot @ 2½ Cents per K.W.	Remarks
						Volts	Amps.	K.W.	H.P.				
1	⅝ × ⅜	Unwelded	36330	22100	100%								2
2		2.47	43190	17480	79%	110	102	11.21	15.0	.113	1.491	$.037275	
3	Same as above	2.48	38580	15570	70%								
4		2.50	32470	12980	58%	119	115	13.70	18.3	.278	3.800	.095000	Specimen Weld Burnt Through
5	Same as above	2.51	53000	21120	96%								
6		2.50	57760	23100	104% Base Material	130	117	15.20	20.4	.312	4.750	.11850	Specimen pulled Base Plate Failed
7	Same as above	2.51	52060	20740	94%								

Type	Deflection at Center Supports	Bending Load	Load per Inch of Weld	Remarks
	3 ¼"	21000	8400	Bent Through an Angle of 65° Before Fracture
	4 ⅝"	20000	8000	Bent Through an Angle of 90° Before Fracture
	3 ¼"	75250	30100	Bent Through an Angle of 90° Before Fracture

APPENDIX 3: DESCRIPTION OF OUTFIT FOR WELDING USING THE QUASI-ARC SYSTEM

General.

The welding outfit, which is a modified form of the metallic arc or Slavianoff process, is simple and embodies no complicated or intricate apparatus. It is applicable to either direct-current or single-phase alternating-current circuits.

Direct-Current Outfit.

Current and Voltage.—The direct-current outfit will operate on from 90 to 120 volts with an arc voltage of 30 to 40 volts and current consumption of 30 to 250 amperes, depending on the size of the object being welded. The maximum piece of work that can be welded will not require more than 250 amperes.

Voltages under 90 volts will not penetrate cool slag.

Equipment Required.—Current-control rheostat; weldtrode holder (bronze) with flexible cable; welder's screen; observer's screen; chipping hammer; wire brush; assortment of weldtrodes.

Control Rheostat.—The rheostat is made from 78 iron grids, each grid having a resistance of 0.03 ohm. There are 16 taps, made of split copper strips clamped between the grids and connected to cone-shaped bronze terminals. The connectors are made of asbestos-covered copper wire.

The grids are inclosed in a perforated sheet-steel box approximately 16x18x24 inches. On the front of this box is a slate panel, on which are mounted the bronze terminals. The resistance is changed by shunting in or out groups of the iron grids. The shunt consists of a bronze plug, which fits securely over the above-mentioned terminals, and a short flexible cable connecting plug to one end of rheostat.

Holder for Electrodes.—Holder is made of bronze, and the handle is insulated with a composition of soft rubber. Heavy leather gloves are required for use in operating these electrodes, due to the presence of ultra-violet rays.

Welding Shield.—The same welding shield which is at present used with arc welding is applicable to this system, but the shields of blue and green are considered preferable by the Quasi-Arc Weldtrode Co., Inc.

Weldtrodes.—The weldtrodes are made from various grades of steel rods. These are coated with an asbestos composition under which is run a fine aluminum wire, extending the full length of the weldtrode. The aluminum acts as a cleansing agent and helps to float away the slag formed while welding.

Advantages of Coating.—Permits contact so that full length of rod may be used. Permits application of metal where required. Prevents drawing arc to the side, thereby permitting reaching through holes, etc. Concentrates heat by insulation. Protects fused metal from oxidation.

Weight.—The complete outfit weighs approximately 350 pounds. The current-controlling rheostat weighs about 260 pounds.

Alternating-Current Outfit.
Single Phase.

Current and Voltage.—This outfit operates on 60-cycle alternating current of 90 to 120 volts, requiring the same current amperage as in the direct-current outfit.

Equipment.—Requires the same equipment as for the direct-current outfit. For supply systems of 220 volts or higher, a small step-down transformer is used in connection with the rheostat.

Multiphase.

Current and Voltage.—Transformers are being built for standard voltages of 220 to 550 volts and frequencies of 25 and 60 cycles.

Indicated voltage across secondary with no current is about 70 volts and when welding 30 to 40 volts.

Equipment.—For this outfit a special transformer is required in place of the rheostat used in the direct-current outfit; otherwise the equipments are the same.

Special Transformer.—The transformer is a special regulator type. It is provided with a shifting core to obtain current regulation. Shifting the core varies the density of the flux cutting the coils, which changes the value of the induced E. M. F.

Weight.—The outfit weighs approximately 300 pounds; transformers about 160 pounds.

Cost.—Rheostat, $175; alternating-current transformer (according to phase and voltage), $200 to $375; holder for weldtrode, $7; cable, 25 cents per foot; weldtrodes, as per price list.

Report No. 21

TESTS OF ELECTRIC ARC WELDING CARRIED OUT AT THE SCHENECTADY WORKS OF THE GENERAL ELECTRIC COMPANY MARCH TO JULY, 1918.

(A)—Outline of Tests
(B)—Report of Results

ELECTRIC ARC WELDING TESTS

Bearing in mind that arc welding with bare metal electrodes has been almost exclusively used in America whilst flux-covered metal electrodes are mainly employed in Britain, it was decided during the early part of my visit, to make use of Sapper J. M. Muir, in the welding of test pieces. It was expected that the result of such tests would provide reliable data of the relative advantages of the work carried out by the different types of flux-coated electrodes besides constituting a comparison between these, and the bare metal electrodes. It was also desired to obtain such data as would define the appropriate fields of application of each type of electrode.

Admiral Bowles directed Mr. MacNary and myself to conduct such practical tests and instructed the General Electric Company to provide the necessary apparatus and facilities at Schenectady for the work to be carried on without interruption.

Owing to the available quantity of flux-covered electrodes other than the Quasi Arc type, being insufficient to complete the minimum number of test pieces required to institute intelligent comparison, it was subsequently decided to limit the programme to Quasi Arc versus Bare Metal electrodes; Sapper Muir and a Quasi Arc operator making welds with the former, whilst expert operators provided by the General Electric Company should carry out the bare electrode work.

It is desired to call attention to the care and zeal displayed in connection with these experiments by Mr. E. G. Gilson, whose report of the results with conclusions, is as under:

SECTION A—OUTLINE OF TESTS.

Outline of Tests to be conducted for Captain Caldwell and Mr. MacNary, for the purpose of comparing relative merits of welds made with flux-covered electrodes (Quasi Arc) and bare wire electrodes.

Samples are to be prepared by welding together two plates about 12"x24" so that a test plate about 24"x24" welded through the middle is obtained. From this test plate samples are cut as indicated by sketch attached.

So far as possible, all test plates should be cut from the same large sheet plate and so arranged that the weld is made along the cut that separated the two plates being welded, thus insuring the reconstruction on the original plate with all parts in the same relative position.

Three thicknesses of plates (⅛", ⅜" and ¾") shall be used, from each of which the following samples shall be prepared:

No Samples

	Quasi Arc		Bare	
Position Welded	D. C.	A. C.	D. C.	A. C.
Flat	4	4	4	0
Horizontal	4	4	4	0
Vertical	4	4	4	0
Overhead	4	4	4	0

The ⅛" plates should be left with square edges. The ⅜" plates should be beveled along the cut to be welded, so that an open angle of 60° is left. The ¾" plate should have an open angle of 45°.

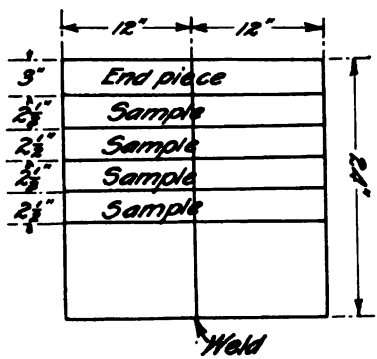
After welding, the sample should have excess metal machined from each side, so that section through weld is uniform and approximately the same thickness as the plate. A sample of the plate material shall also be tested.

The Quasi arc welding is to be done by Captain Caldwell's operator, Mr. Muir, unless otherwise specified by Captain Caldwell. During the time that he is working on these plates, care must be exercised that Mr. Muir is not interrupted in any manner whatsoever. The bare wire samples are to be welded by an operator who is satisfactory to Mr. MacNary. When welding is being done record should be kept of the time of each application, number of applications, size and number of electrodes to each joint, current and voltage used, etc.

Tests.

Two of the four samples from each test sheet are to be tested for tensile strength; the other two are to be tested for bending. In tensile strength, the yield point, final rupture, elongation, and necking, if any are to be noted. The bending test may be made by supporting the pieces upon two piers not less than 14″ apart, and applying a load over the weld which is located midway between the piers. The load should be applied in such manner that bending will take place about a 2″ radius. In this test, the angle of deflection, yield and load to rupture should be noted.

HOW SAMPLES ARE CUT FROM TEST PLATES



SECTION B.

REPORT OF RESULTS BY MR. E. G. GILSON.

(Not Yet Complete.)

Report No. 22

BIBLIOGRAPHY OF ELECTRIC WELDING.

This bibliography was prepared for me by Mr. John Liston, who, in this connection, obtained the co-operation of the various libraries of the General Electric Company.

[The 1918 section of this bibliography has been contributed by Prof. Bradley Stoughton.]

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